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ALUMINUM: how it's made and where it's used

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ALUMINUM

how it's made and where it's used

Part I
The Story of Aluminum

Part II
Uses of Aluminum

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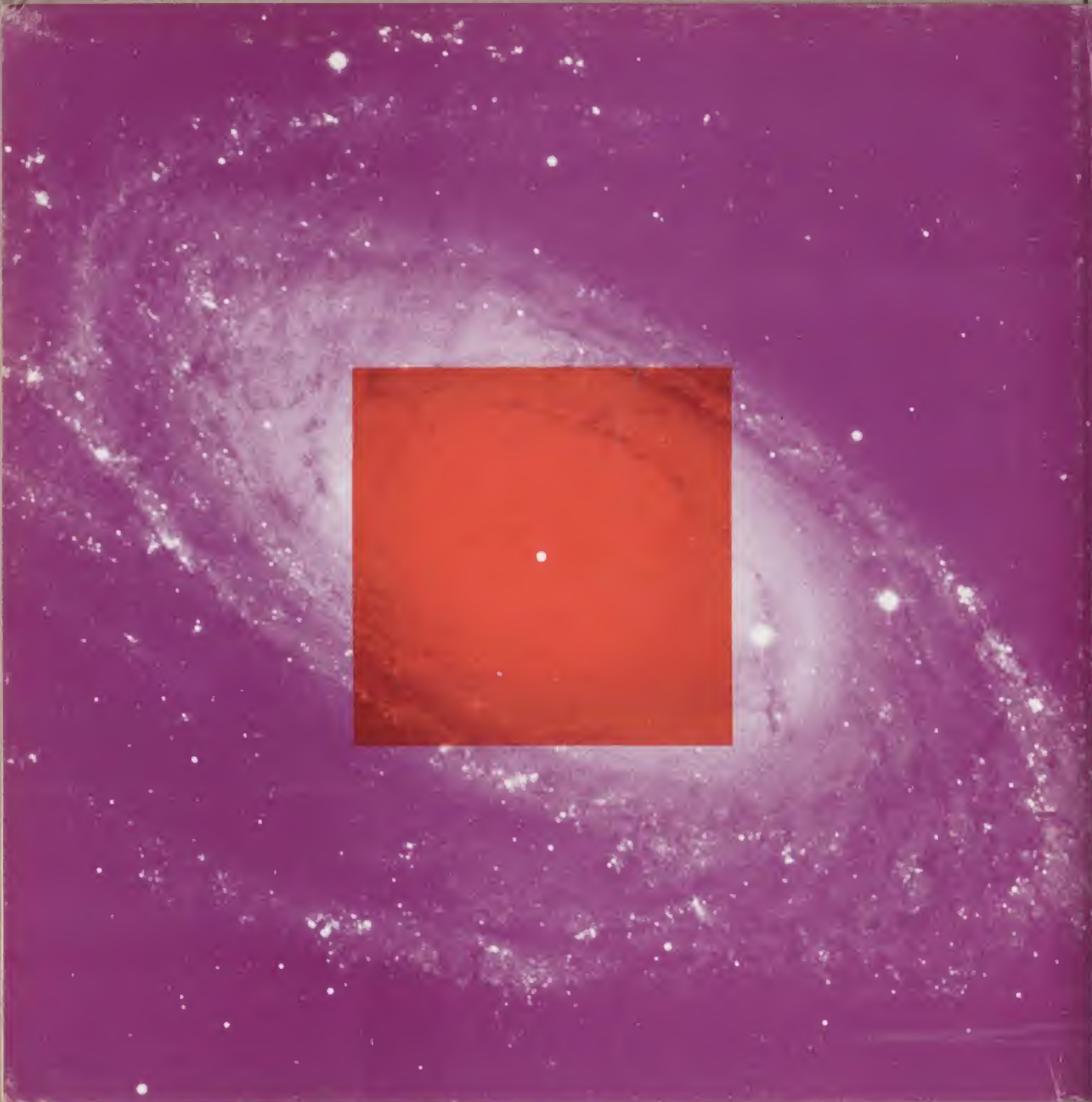
THE STORY OF ALUMINUM

THE ALUMINUM ASSOCIATION



ALUMINUM is one of about a hundred basic building blocks or elements out of which our physical universe is built. As such, it dates back to the beginning of time and to the first creation of material things. According to current scientific theory, the universe as we know it began to form 12 to 15 billion years ago . . .

At that time, vast clouds of cold hydrogen boiled and writhed, hard driven by currents of electromagnetic force. The clouds were made up of billions of atoms, each of which can be imagined as consisting of a nucleus (like a tiny sun) around which an electron (like a tiny world) circled in orbit.

in the beginning

Accelerated to speeds approaching that of light by the constant pressure of electromagnetic forces, the hurtling clouds collided. The atoms of hydrogen smashed each other into the raw and elemental stuff of which they were compounded. In the wreckage after the collision was something that was no longer hydrogen; perhaps a weak and unstable form of helium. This material, colliding with other fragments and with whole hydrogen atoms, created new and different pieces of matter. Later on, when the stars condensed from the hydrogen, internal pressures turned them into vast nuclear furnaces, where great heat and powerful internal pressures created most of the natural elements we know today—among them aluminum.

The aluminum atom has a central nucleus "sun" and 13 electron "worlds" circling about it. The electrons are grouped in definite orbital zones with three of the electrons in orbits quite far from the nucleus. Because of this distance, these three electrons are held less strongly by the attractive force of the nucleus, and are therefore able to combine easily with the atoms of other elements to form new alloys with many useful properties.

At the time it was first created, aluminum instantly combined with many other elements, so it is not found in metallic form in nature.

The resulting compounds were extremely durable — ("refractory", metallurgists called them)—and resistant to heat and chemicals. With oxygen, aluminum formed what today we call the sapphire, the ruby, the Oriental amethyst, and the Oriental emerald; with fluorine and silicon it formed the topaz: with silica it formed the micas, garnets and feldspars; with phosphate the turquoise and with silica, soda and oxygen—jade. The crystalline forms of some of these compounds, forged in the heat and pressures of creation, are considered gems by men.

More importantly to the world's economies, when Earth's mass cooled, aluminum mixed with water and oxygen to form the original material from which bauxite— the ore of aluminum—was made. When the crust of the earth finally congealed, it was permeated with aluminum, silicon and oxygen—the main components of the Earth's skin.

These ancient aluminum-silicon rocks were the hard outer shell of the world when it was young. As Earth aged, the great rocks were split by frost and heat, sculptured by ice, drenched with rain, scoured by wind; moved and jostled and bumped and carried by rivers and streams; splintered and rounded and ground and polished by the fragments of themselves.

In the long cycles of time, through physical

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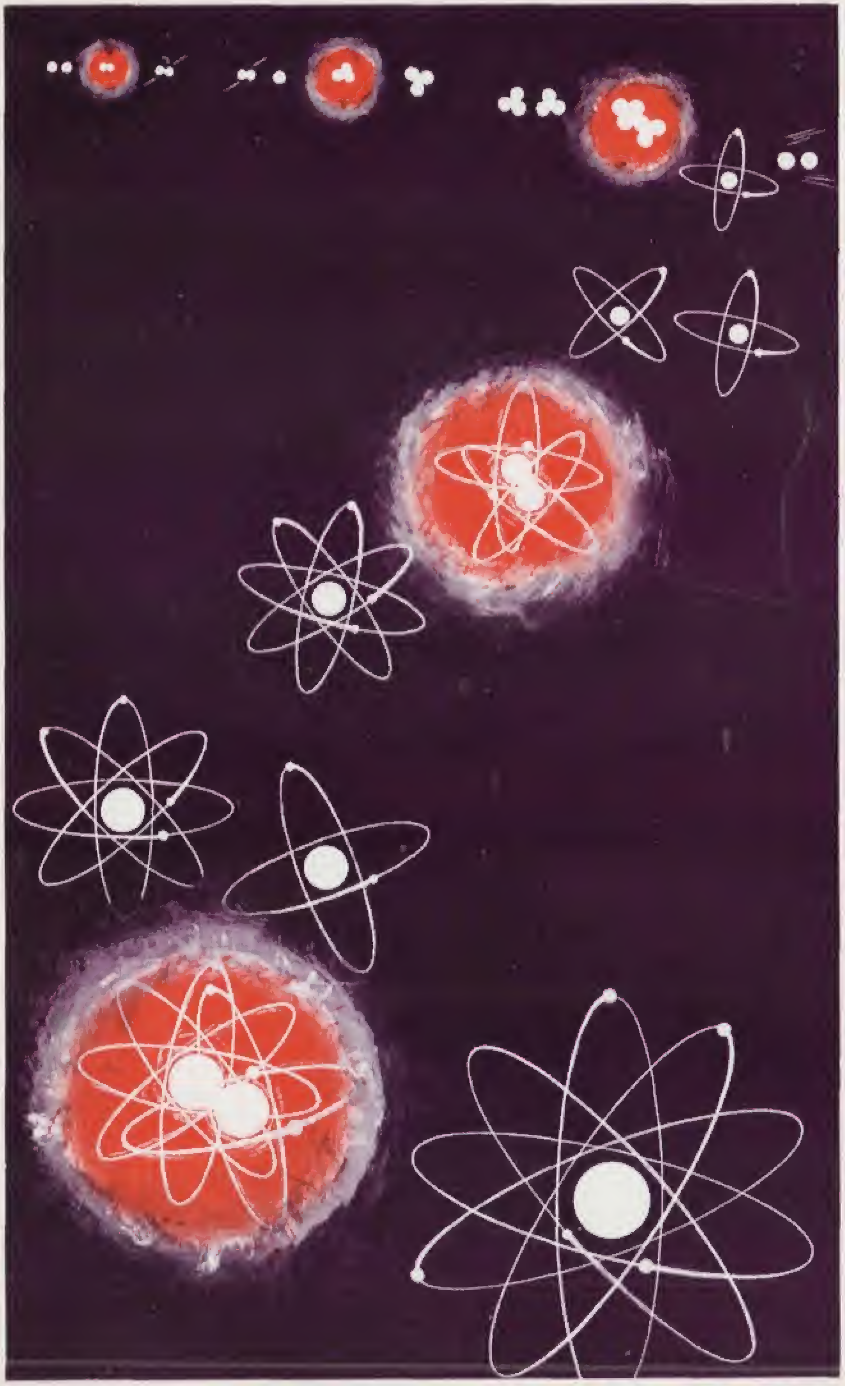
GALAXY PHOTOGRAPH FROM THE MOUNT WILSON AND PALOMAR OBSERVATORIES.



It is believed that aluminum, like all the other elements, was originally formed through successive collisions of hydrogen atoms under high temperatures and great pressures during the birth of our solar system. Artist's conception, at left, shows how a chain of collisions could result in increasingly complex atoms, including aluminum. Drawing below shows what an aluminum atom might look like to someone standing on the central nucleus and looking out across the closest electrons to the ones furthest out. The three electrons furthest from the nucleus are largely responsible for aluminum's qualities.

ALUMINUM ■
THE MOST ABUNDANT METAL

In order of their abundance in the earth's crust, fifty miles deep, the most abundant elements are:

ELEMENT	PARTS PER 1000
Oxygen	466
Silicon	277.2
Aluminum	81.3
Iron	50.0
Calcium	36.9
Sodium	28.3
Potassium	25.9
Magnesium	20.9

and chemical action, the particles became exceedingly fine, forming the aluminous clays from which the major portion of today's clay "refractory" products are made.

In a wide band around the world, where the sun was hottest and the rain hit hardest, the clays and other aluminum compounds were baked and pounded and the impurities leached out, leaving an ore which has a high content of aluminum oxides.

These oxides regrouped into new patterns, and the molecules into which the aluminum oxide atoms joined also drew a large amount of water into their crystal lattice.

This new compound, of which there are a number of different types, was called bauxite after Les Baux, France where it was first discovered in 1821. As decades passed and man learned to produce aluminum from a variety of weathered minerals, the word "bauxite" continued to be used as the convenient name for all the varieties actually used today to make aluminum metal.

Bauxite has been found on every continent except Antarctica, spread in a wide belt through the tropical and sub-tropical areas of the earth. Usually—although not always—it lies in rather shallow deposits close to the surface, and is mined with power shovels or draglines. As it is dug out of the deposits, the bauxite ranges in color from yellowish-white to dark, plum-like red, depending on the amounts of iron oxide and other impurities it contains. It may be in the form of fine powder, or granules or lumps, or as a sort of sticky clay. It has some free water in it, which is driven off by heating it in kilns, and the ore itself is ground into small pieces for easier processing.

In each of these pieces, the original metallic aluminum still is locked with other elements in a grip that has lasted the billions of years since it was originally formed, even though bauxite—as such—was created a relatively short time ago, in the long span of geologic time. In order to break this extraordinary chemical and physical bond, man must figuratively turn back the clock billions of years and subject the elements to much the same kind of electrical forces that formed it in the first place.

Only then does aluminum flow from rock and become the pure metal it was when it was originally created. ■

To some extent, there is a little aluminum (although not in metallic form) in almost any handful of earth. But, with the methods used today, only earth with an aluminum oxide content of 45 per cent or more is considered practical for making metal economically. The richest deposits have been found in a wide band extending on either side of the equator. Known deposits hold enough reserve to furnish the world with aluminum for thousands of years and new deposits are still being discovered. Most (but not all) of the deposits are relatively shallow and close to the surface, making them easy to mine with power shovels and draglines (photo).

in search of the invisible

FOR MANY CENTURIES
MEN TRIED TO FIND
"THE METAL OF CLAY" (ALUMINUM)
WHICH GAVE POTTERY
ITS SPECIAL PROPERTIES

ALTHOUGH ITS DISCOVERY as a metal did not come until some 7,000 years later, aluminum nevertheless was one of the first earth materials put to use by man. About 5300 B.C. in Northern Iraq, the art of pottery making was developed. The clay used for making the best pottery consisted largely of a hydrated silicate of aluminum.

Primitive man took clay (perhaps exposed on river banks), mixed it with water, and beat it into thin sheets on a flat rock, or the ground. The sheets could then be formed into the shape of vessels and placed in the sun or beside a fire to dry. Once dry, the clay became "as hard as stone," and could be used for carrying water or for cooking.

Thus the pottery makers, in using aluminous clays to form cooking utensils, forshadowed by thousands of years one of the earliest uses of the metal itself.

Certain other aluminum compounds such as the "alums" were in widespread use by the Egyptians and Babylonians as early as 2000 B.C. in vegetable dyes, in various chemical processes and for medicinal purposes.

Despite this early beginning, after nearly 7,000 years of use, all the skills of man had not succeeded in separating "the metal of clay" (as it was called) from its age-old bondage to the other elements of the earth. It could not be separated by chemicals or with quicksilver, nor beaten out with hammers, nor driven forth by fire, as could be done with most other known metals.

It was not until the middle of the 18th Century that chemists began to believe that alum contained two bases, and not just *terra calcaria*—a limelike substance with which alum had been identified since 1702.

In 1782, the great French chemist Lavoisier said, "It is highly probable that alumine is the oxide of a metal whose affinity for oxygen is so strong that it cannot be overcome either by carbon or any other known reducing agent."

Lavoisier 1782

Sir Humphry Davy, who had already isolated potassium, sodium, calcium, barium, boron, magnesium and strontium by electrolytic methods, turned his attention to aluminum in 1807. But he was unsuccessful.

Sir Humphrey Davy 1809

Despite his failure, he was convinced that this material was an oxide with a metallic base, and to this hypothetical metal he gave the name "aluminum," which he felt sounded more scientific than the popular "metal of clay," and which preserved a natural relationship to the Roman "alumine." (Davy's spelling is still used in the United States; but elsewhere in the world the spelling "aluminium"—following that suggested by H. E. Sainte-Claire Deville—is used.)

In 1809, Davy fused iron in contact with alumina in an electric arc and produced an iron-aluminum alloy. For a split instant, before it joined the iron, aluminum existed in its free, metallic state for perhaps the first time since the world was formed.

H. C. Oersted, in 1825, told the Royal Danish Academy of Sciences in Copenhagen that he had found "the metal of clay." He had produced a small lump of aluminum by heating potassium amalgam with aluminum chloride and found aluminum embedded in the amalgam. For the first time, man had a process for making metallic aluminum. "It forms,' said Oersted, "a lump of metal which in color and luster somewhat resemble tin . . ."

Oersted 1825

Two years later in Berlin, Friedrich Wohler repeated Oersted's experiment, but failed to produce aluminum, and it was not until 1845, working at the University of Gottingen, that he succeeded in making metallic aluminum in particles "as big as pinheads." He said that the metal is "light, ductile, stable in air, and can be melted with the heat from a laboratory blowpipe."

Sainte-Claire Deville, in 1854, announced to the French Academy of Sciences that he had made some improvements in Wöhler's method. He substituted sodium for potassium and found that this process enabled the separate globules of aluminum to coalesce into "lumps the size of marbles." Since sodium was so much cheaper than potassium, the way to a commercial process for producing aluminum had been found.

Deville's advances founded the chemical aluminum industry, in which aluminum was produced in relatively large (compared to laboratory production) quantities by purely chemical means and without the use of electrolysis. Commercial plants using the process were operating in France in 1855. Bars of

aluminum made in them were exhibited—next to the crown jewels—at the Paris Exposition of 1855; the first time the general public had ever seen, or perhaps even heard of, aluminum.

The French Academy contributed 3,000 francs to stimulate further research on aluminum and Emperor Napoleon III, hoping that aluminum could be used as lightweight armor for his troops, also encouraged Deville with

Deville 1854

10 money and support. (Napoleon's most honored guests were served with aluminum forks and spoons; lesser guests had to be content with gold and silver. The infant Prince Imperial flourished an aluminum rattle, and an aluminum watch chain was devised and presented by Napoleon to the King of Siam on his visit to Paris.)

By this time, the cost of the metal, which at first had been "priceless" and then in 1852 was available at \$545 per pound—dropped dramatically to \$115 per pound by 1855 and to about \$17 per pound by 1859, when the French plants went into full production.

Even so, the chemical process produced aluminum at too high a cost for widespread use, and it was soon to be superseded by an electrolytic process. Strangely enough a workable electrolytic process, which had eluded Davy and other chemists for three-quarters of a century, was discovered almost simultaneously — and completely independently — by two young men, one in the U.S. and one in France.

Charles Martin Hall, while a student at Oberlin College, Oberlin, Ohio, became interested in aluminum and began experimenting to find a better and more economical way to produce it. He continued his work in a backyard woodshed after graduation and, after many trials, discovered a workable electrolytic process on February 23, 1886. At almost exactly the same time, Paul L. T. Héroult, of Paris, France, working in a borrowed laboratory, discovered the same process.

Charles M Hall 1886

By an odd coincidence, both men were born in 1863 and both were destined to die in the same year—1914.

In 1888, a German chemist, Karl Joseph Bayer, was issued a German patent for an improved process for making pure aluminum oxide (alumina) from low silica-content bauxite ores, and the foundation of the aluminum age was complete.

Héroult 1886

The contribution these men made to the world is enormous, for the Bayer and Hall-Héroult processes freed—for the uses of man—the world's most plentiful and versatile structural element . . . ■

How Advances in Aluminum Technology Have Made It One of the Most Economical Metals

prices per pound prior to Hall process

1852	\$545.00
1854	272.00
1855	113.30
1856	34.00
1857	27.20
1858-1885 . .	11.33
1886	7.85
1888	5.25
1890	2.25

after introduction of Hall process

1895	.52
1900	.33
1910	.22
1920	.33
1930	.24
1940	.19
1950	.18
1960	.26
1964	.24

the time machine

BY TURNING THE GEOLOGICAL "CLOCK" FORWARD AND BACKWARD, METALLIC ALUMINUM IS SET FREE

PART THREE/ the time machine

IN ESSENCE, the world's aluminum producing industry is a gigantic "time machine," for what it really does is to move events forward and backward in time in order to re-create the sort of environment in which aluminum can exist in its free metallic form.

One end result of the millions of years in which the ancient aluminous rocks have been pummeled and beaten and drenched and leached, has been to increase the aluminum oxide content of bauxite.

Techniques used by the aluminum industry accelerate this process, and add new ones not found in nature, to remove impurities untouched by natural processes.

What men do, in the plants of the aluminum industry that reduce bauxite to aluminum oxide, is to turn the geological "clock" forward. They substitute roaring steam and boiling water for the heat of the tropic sun; powerful caustic solutions for the mild ground water left from tropical rains; and, for the long cycles of monsoon and drought, men collapse the work of millions of years into a matter of days and hours in a high pressure universe contained in tanks and pipes.

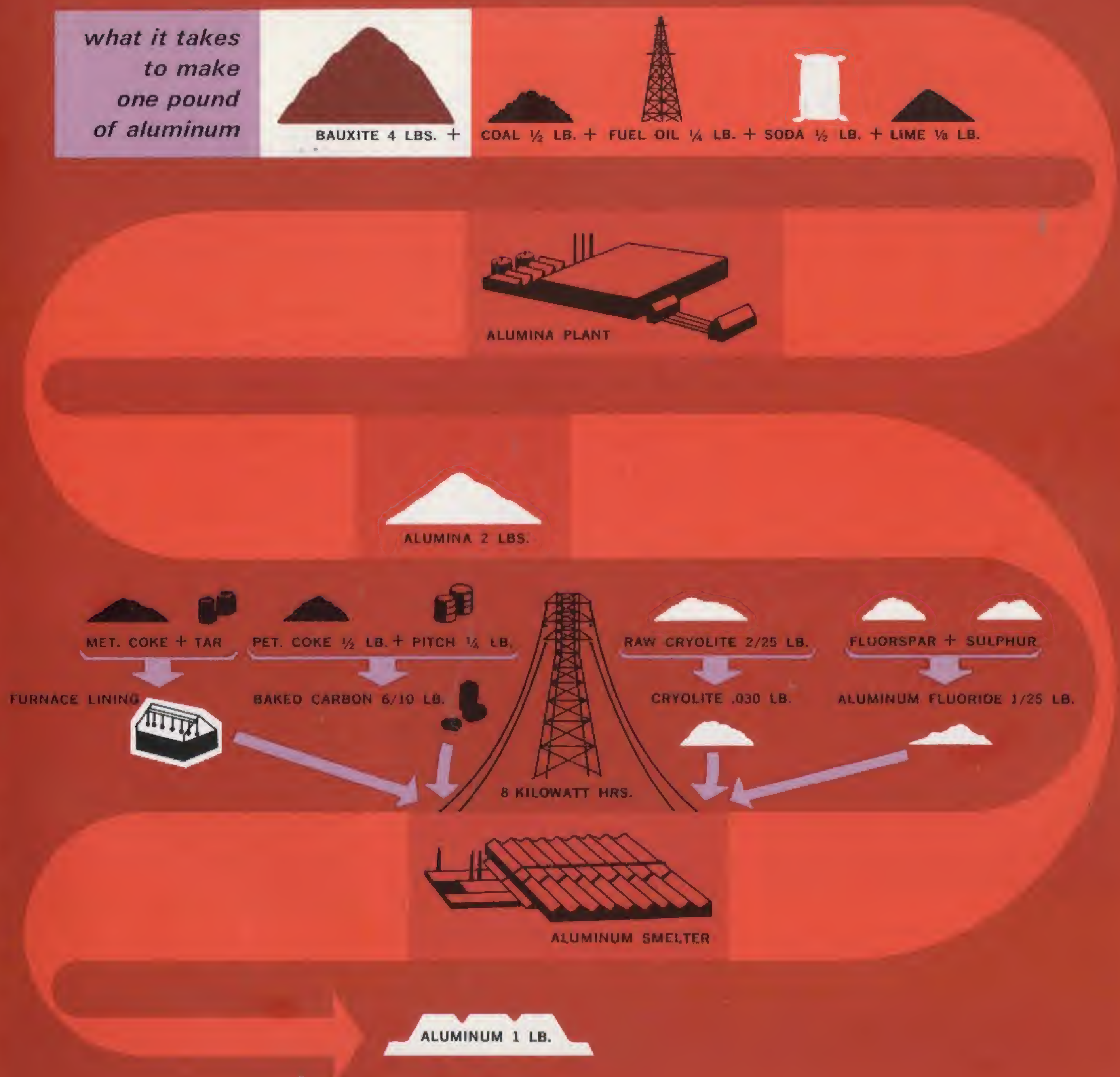
Time is greatly shortened and, in the end, the almost totally pure aluminum oxide—alumina—stands free, but with aluminum and oxygen still locked together so strongly that only the ingenuity of man and the power of electricity can tear them apart . . .

Considered imaginatively, the potlines of the world's aluminum producers are designed to approximate the environment in which aluminum was born.

For the original material of that long-ago time, man substitutes the relatively simple combination of aluminum and oxygen. For the original heat and pressures, man substitutes the heat of molten metal and flux confined in a crucible of steel lined with carbon. For the raw force of the writhing, twisting electromagnetic fields, man substitutes powerful electrical currents, pulsing through the molten bath.

Through the action of the electrical current, the bond between the oxygen and the aluminum atoms is broken. The oxygen attaches itself to the carbon and the aluminum goes free, protected from attaching itself to any more oxygen by a crust of molten flux above it. When the molten metal is tapped or siphoned and emerges into the atmosphere, the very outer atoms combine again with oxygen, forming a tough, durable "sheath" of alumina, shielding the inside atoms of aluminum from further contact with oxygen.

Thus man frees the world's most abundant and versatile metal for his use. ■


what it takes to make one pound of aluminum
BAUXITE 4 LBS. +
COAL ½ LB. + FUEL OIL ¼ LB. + SODA ½ LB. + LIME ⅛ LB.
ALUMINA PLANT
ALUMINA 2 LBS.
MET. COKE + TAR
PET. COKE ½ LB. + PITCH ¼ LB.
RAW CRYOLITE 2/25 LB.
FLUORSPAR + SULPHUR
FURNACE LINING
BAKED CARBON 6/10 LB.
CRYOLITE .030 LB.
ALUMINUM FLUORIDE 1/25 LB.
8 KILOWATT HRS.
ALUMINUM SMELTER
ALUMINUM 1 LB.

how aluminum is made

chemically

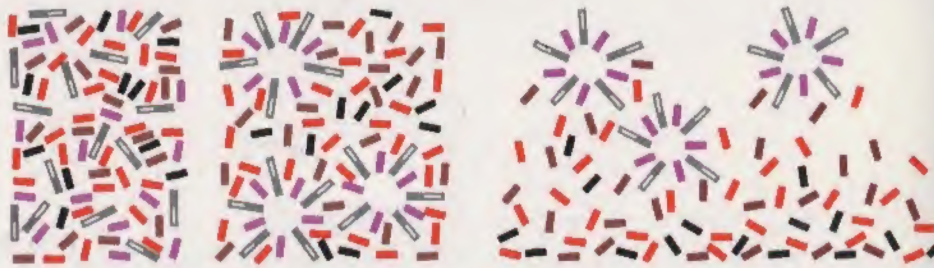
Bauxite, the raw ore of aluminum, is made of from 45 to 60 per cent aluminum oxide, 3 to 25 per cent iron oxide, 2.5 to 18 per cent silicon oxide, 2 to 5 per cent titanium oxide, up to one per cent other impurities, combined with 12 to 30 per cent "water of crystallization." Depending on where it is found, the ore varies greatly in the proportions of its constituents, and in color and consistency. ▶

The dried, ground bauxite is mixed with a solution of caustic soda (sodium hydroxide) which dissolves the alumina to form sodium aluminate. The silica in the bauxite reacts and precipitates out of solution. The iron oxide and other impurities are not affected chemically and, being solids, settle out. ▶

The "green liquor" is now highly supersaturated *sodium aluminate*, a man-made chemical that is too reactive to exist in nature. Previously prepared hydrated alumina crystals are added to the solution. These seeds attract other crystals and form groups that become physically heavy enough to settle out of the solution. The partially "spent" liquor is returned to be mixed with fresh bauxite slurry and then goes through the cycle again. ▶

physically

A bit of bauxite might be imagined to look something like the drawings at right in which different colored rods represent, proportionally, the chief ingredients: grey/white for alumina; purple for water; red for iron oxide; brown for silica, and black for other impurities. The ingredients can be separated by chemical, mechanical, thermal and electrolytic actions. ▶



industrially

A typical modern bauxite plant is shown in the photograph above. The free water is removed from the ore by heating in rotary kilns after it has been ground up into a uniform particle size. Installations like these are found throughout the world, wherever large deposits of bauxite are being mined. ▶

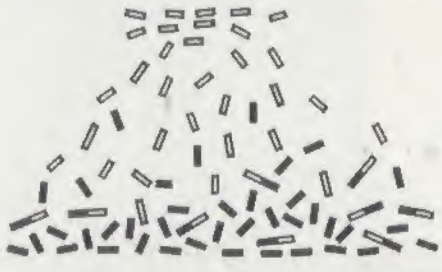
These huge precipitator and thickener tanks correspond to the laboratory beaker shown above. The mixture is allowed to stand and the "red mud" containing the impurities, settles to the bottom. The clear "green liquor" —largely sodium aluminate—is drained off. ▶

In these precipitator towers, as tall as five-story buildings, the hydrated alumina crystals are added to thousands of gallons of supersaturated sodium aluminate. More hydrated alumina is precipitated from the supersaturated solution, forming sandy crystalline agglomerates. ▶

After being washed to remove any remaining traces of impurities, concentrated aluminum hydrate crystals are roasted at temperatures of more than 2000° F. The water is thus driven off and the resulting alumina remains as a fine, white powder, similar to sugar in appearance and consistency. It is now half aluminum and half oxygen, bonded so firmly that neither chemicals nor heat alone can separate them. ▶

Alumina, cryolite (sodium aluminum fluoride) and aluminum fluoride are mixed together in a steel container or cell lined with carbon. A carbon electrode is lowered into the mixture and direct electrical current is then applied. The current is carried by the now molten mixture of cryolite and aluminum fluoride to the carbon cathode lining the cell. The oxygen joins the carbon in the anode as carbon dioxide; the aluminum is free. ▶

The molten metallic aluminum collects in a layer above the carbon that lines the bottom of the electrolytic cell and below the crust of white, not-yet-dissolved alumina. From time to time, a part of the molten metal can be tapped or siphoned off into crucibles and more alumina charged into the cell. Since the carbon anode is slowly eaten away as the oxygen joins it to form carbon dioxide, the carbon in the anode has to be replaced periodically. ▶



In these long, slightly inclined tubes, the washed aluminum hydrate crystals are turned and roasted. Gravity carries the now dry alumina to storage and the water is driven off as steam and vapor. The alumina, in addition to forming the processed material from which metallic aluminum can be made, is an important chemical in its own right and finds widespread use in the chemical, refractories, ceramic, electrical and petroleum industries. ▶

This is a "potline" in a modern aluminum smelting or "reduction" works. It is called "reduction" because the process that takes place here quite literally reduces the alumina molecules to metallic aluminum. The "pots" are rectangular steel cells lined with carbon. They are wired together in a series, with direct current moving into them through the carbon anode, through the mixture of chemicals in the pot, and out through the carbon cathode lining of the cells. ▶

Depending on the design of the cell, the molten aluminum may be tapped from the side of the pot or siphoned off into giant crucibles which have been preheated so that the metal will not chill and solidify. The quality of the metal is constantly being checked by laboratory analysis, and the percentage purity of the metal in the crucible may be chalked on its side. The molten metal is now ready for casting or further alloying before casting. ▶

a family of aluminum metals

THE METALLIC ALUMINUM that is produced by modern refining processes emerges from the potlines as 99.5% pure aluminum, the .5% remainder being tiny traces of other elements that the refining process has not removed. From this basic aluminum, a whole "family of metals" can be produced. Further refining can produce "super purity" aluminum, which is 99.99 pure and is used as a catalyst carrier making high octane gasoline, for forming jewelry and, in the form of foil, it is used by the electronics industry.

Aluminum with a purity of at least 99.0% is assigned to the "1000 Series" of alloys.

However, most aluminum is used today as an "alloy." For instance, here are some of the alloying metals and their principal effects:

COPPER—makes alloys heat treatable; increases strength and hardness

MAGNESIUM—increases tensile strength, marine corrosion resistance, weldability and hardness.

MANGANESE—improves natural strength and corrosion resistance.

SILICON—lowers melting point, improves castability, and in combination with magnesium, yields heat treatable alloys with good formability and corrosion resistance.

ZINC—tends to improve strength in hardness, and in combination with small percentages of magnesium, yields heat treatable alloys with very high strength.

In addition to the common alloying elements listed above, numerous other metallic elements are added in varying amounts to improve properties of the basic families of alloy or to provide special effects. Representative examples include: (a) bismith, lead and tin give improved machinability; (b) beryllium improves the welding and casting characteristics; (c) boron helps increase electrical conductivity; (d) chromium, zirconium and vanadium are used to provide special effects; (e) nickel gives improved strength at elevated temperatures; (f) titanium exerts a powerful grain refining effect which improves strength and ductility.

The range of useful alloys is constantly being increased through research. ■

Aluminum/Magnesium Silicon Alloys—6000 Series
The best-known members of this family are alloys 6061 and 6063 which have good formability, high resistance to corrosion, are readily welded, machine easily and can be finished in many ways. End uses include architectural installations, transportation equipment, bridge railings, and welded constructions.

Other Alloys—8000 Series
Aluminum can also be alloyed with elements other than those so far shown; beryllium, bismuth, boron, iron, lead, nickel, sodium, tin, titanium, and zirconium. Where one of these is the dominant alloying ingredient, then the alloy would be designated with a number starting with 8000.

Aluminum Alloys—1000 Series
Commercially pure aluminum, containing not more than one per cent of other elements. Formability, weldability and ability to take a finish are good to excellent, corrosion resistance and electrical conductivity are very high; strength is limited. Typical end uses include chemical equipment, reflectors, heat exchangers, architectural applications, and decorative trim.

Aluminum/Magnesium Alloys-5000 Series
When from 0.3 to 5 per cent of magnesium is added to the aluminum, the resulting alloys have moderate to high strength, good weldability and generally good resistance to corrosion in marine atmospheres. Uses include architectural, ornamental and decorative trim, appliances, street light standards, ships and boats, cryogenic tanks, gun mounts and crane parts.

Aluminum/Manganese Alloys-3000 Series
Addition of about 1.2 per cent manganese yields aluminum alloys that have about 20 per cent more strength than pure commercial aluminum, but retain high workability. Alloy 3003 is the "workhorse of the industry" and typical end uses include cooking utensils, heat exchangers, storage tanks, awnings, furniture, highway signs, roofing, siding and numerous architectural applications.

Aluminum/Copper Alloys—2000 Series
Copper is the chief alloying ingredient in this group. The alloys in this series may exceed the tensile strength of mild steel as much as 50 per cent. Corrosion resistance and weldability are limited. Some alloys in this family have superior machinability. Members of this family are particularly suited for parts and structures requiring a high strength-to-weight ratio and are commonly used to make truck-trailer panels and aircraft structural parts and for those requiring a good strength at elevated temperatures up to 300°F.

THERE IS NOW CREATED a metal that is remarkable—not only for a particular quality—but for a combination of qualities that make it unlike any other material available to man. It is lightweight—weighing only about one-tenth of a pound to the cubic inch, approximately one-third as much as the same amount of steel, copper or brass.

It is strong;

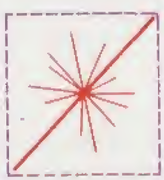
some aluminum alloys actually exceed structural steel in strength. It has high workability, responding easily to every form of metalworking known to man. It works easily with primitive tools and muscle power and it works easily with high speed, power-driven machinery. It has excellent corrosion resistance

against attacking elements in the atmosphere, water (including salt water), oils and many chemicals. It is highly reflective

to radiant energy—visible light, radiant heat and radio and radar waves. It has high thermal conductivity

and, on a weight basis, aluminum is the most efficient heat conductor of the common metals. It has high electrical conductivity,

conducting the same amount of electrical current as copper at half the weight. Aluminum is non-magnetic, a property of importance in the electrical and electronics industries, and it has non-sparking characteristics, important when used around inflammatory or explosive materials. Aluminum is non-toxic, making it safe for use with foods and beverages. It has an attractive appearance



in its natural finish, which can be soft and lustrous or bright and shiny, or, if desired, it can be virtually any color or texture. And, finally, because of vast ore reserves it is the most abundant of all the structural metals on earth. If men had had to dream a metal that suited their needs best—it would have been aluminum.


a thousand forms lie waiting

Pure aluminum from the potlines is poured into open hearth furnaces for alloying before casting . . .

THE FORMS OF ALUMINUM

As it is freshly created by the primary aluminum producers, the virgin metal is a lustrous, silvery liquid. It has no shape of its own, any more than water has, except that of the container in which it happens to be at the moment. In form it is nothing—yet is everything, for in it a thousand shapes lie waiting—needing but the hands and minds of men to set them free . . .

THE FIRST THING that happens to the molten aluminum after it is produced in the reduction cells is that it is drawn off into 3500 to 8000-pound capacity crucibles, moved by overhead or traveling crane down the channels between the potlines. Some of the pots are tapped and the metal runs by gravity into the crucible; others are siphoned with a curved cast iron tube, one end of which is placed in the layer of aluminum in the bottom of the reduction cell and the other opens into the crucible. An air hose attached to the siphon is used to draw the vacuum.

When the crucible is full, it is carried along to a furnace which sometimes has two compartments, or "hearths." Into the first of these, the metal from the crucible is poured, as is metal from other crucibles from other lines. This mixes the metal from various reduction cells and thus equalizes slight differences in purity. In the charging hearth, the metal is alloyed, through the addition of other metals, and it is fluxed.

Fluxing is accomplished by bubbling nitrogen or various mixtures of chlorine and other gases through the molten metal. (This is done by inserting a long, perforated "lance" into the molten liquid and pumping the gas through it.) What this does is to force the oxides of aluminum back up to the surface. They have formed on top of the metal while it stood in the crucibles and after being poured into the furnace, and—being heavier than pure aluminum—sink down into the molten metal. Bubbles in the fluxing material surround the aluminum oxide and carry it up to the surface, where it can be skimmed off with big, long-handled rakes—much like skimming the grease off the top of a stew.

After alloying and fluxing, the metal is allowed to flow into the second or "holding" compartment of the furnace, which acts as a reservoir. When the reservoir of molten metal is sufficiently full the metal may be drawn off to be cast.

Actually, it isn't quite as simple as that; certain complex reactions occur in the furnace itself and, as a result, some hydrogen gas is trapped in the molten metal. So, just before it moves from the charging furnace to the holding furnaces, the metal is "degassed" by introducing a combination of nitrogen and chlorine gas, or chlorine gas alone, or other chemicals. Although similar to fluxing in its description, degassing has an entirely different purpose but both may occur in the same operation.

Only now, thousands of miles and dozens of operations since it was mined, is the metal ready to be used . . . ■

ROLLING INGOT

■ **A part of the metal** produced by the primary producers is destined to be used by them and other firms for rolling into sheet and plate. To make this process economical, very large cast slabs of the metal (rolling ingots) are needed. These may be 14 feet long and weigh up to 32,000 pounds.

Rolling ingots are usually cast by pouring the metal into long, rectangular molds, placed vertically. The bottom of the shell is a hydraulic ram, which slowly lowers as the molten metal is poured into the mold. The sides of the mold are cooled by water, "freezing" the molten metal very quickly and at a controlled rate. This process is known as "direct chill" (D.C.) casting, and it results in an ingot that, despite its great size and thickness, is of even, controlled quality all the way through. ■

ALLOY INGOT

■ Metal that is to be sold to other processors must necessarily be cast in smaller sizes, both to make it easier to transport, and for easy handling by the equipment of processors. Consequently, the molten metal is poured from the holding furnaces, or from crucibles that have been filled from the holding furnaces, into a conveyor belt, which is made up of ingot casting molds.

The molten metal pours into each mold, which then moves on, is skimmed of the dross and oxides that rise to the top, cools enroute and, at the other end of the conveyor, is knocked out of the mold and stacked. The ingots run from 4 to 50 pounds each, and are notched and otherwise shaped for special stacking, binding and handling. ■

BILLET

■ The "direct chill" method of casting rolling ingot may also, by altering the size of the molds, be used to produce ingot that can be made into rod, bar and wire products, or billets, which can be placed in extrusion presses (described on page 23).

In these cases, the molds may be square (for rod, bar and wire) or round, if to be used for extruding. The billets look, in the first case, like extra-long railroad ties and, in the second, like peeled logs at a sawmill. They are, indeed, the "timbers" of the aluminum industry, destined to be formed into such important things in everyday life as electrical transmission cable, wire for insect screening, precision parts for all kinds of equipment, lawn furniture, windows, storm doors, architectural shapes for skyscrapers, aircraft and automobile parts, and a hundred other uses. ■

Although the basic principle is always the same, casting can take many forms. In photograph at top, a large permanent mold casting is being poured. Lower photograph shows some of the types of shapes produced by aluminum casting.

ALUMINUM CAN BE CAST

FOUNDRY operators buy their casting ingot from the producers of primary metal. They also buy "secondary metal"—aluminum that is being used for its second, third, or more times, originating as scrap from various fabricating operations and other sources. This is an especially important category of metal (about one out of every five pounds of aluminum consumed each year is "secondary") because when combined with primary metal it lowers the cost of finished products, increases the over-all supply of the metal, and—through reuse—adds increased utility value to the original aluminum.

One of the most ancient of the casting methods is "sand casting." Specially selected sands, often mixed with fine clays and moisture, are molded around a pattern into a shape into which the molten aluminum is poured. When the metal solidifies, the sand is knocked away and the casting stands free. *Permanent mold* casting involves a mold of iron or steel into which the metal is poured, and from 60,000 to 150,000 castings can be produced from a mold before it has to be replaced. In *die casting*, the molten metal does not flow by gravity, but is forced into steel molds by hydraulic pressure. *Shell mold casting* uses a shell of sand that is no more than ⅛ to ⅜-inch thick, which has been preformed and baked in a metal pattern. *Plastermold casting* is a refinement of sand molding in which the mold is made of plaster for improved tolerances and surface finish. *Investment casting* is a two-step process in which wax is first cast in permanent molds, a new mold prepared around the wax, the wax melted, and the molten aluminum poured in the cavity. This process allows putting a number of diverse shapes together, and is economical for very complex pieces. Finally, *centrifugal casting* uses centrifugal force to drive the molten metal into the furthest recesses of the die. ■

ALUMINUM CAN BE EXTRUDED

IT IS OFTEN SAID that "extruding aluminum is like squeezing tooth paste out of a tube," and no one has so far found a more graphic or apt description.

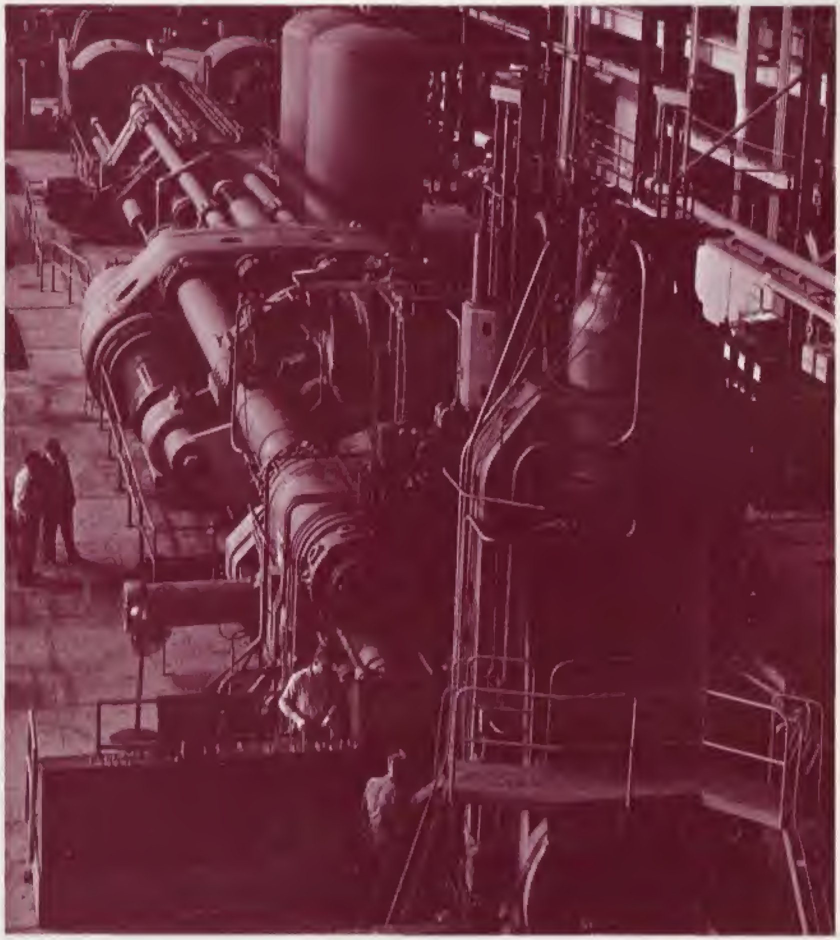
Aluminum extrusions have been used commercially for about 40 years and in greatly increased quantities in the last 15 years, as more was learned about the extruding process and as the advantages of extrusions became more widely known.

In the extrusion industry, billets – the aluminum logs cast by the producers – are cut into convenient lengths, like cordwood, heated in furnaces up to 800°F until the metal achieves the desired plasticity and then pushed by hydraulic rams through a hole cut in a die. The hole may be almost any shape conceivable, and for this reason the number of shapes that can be extruded is virtually infinite. The metal takes the shape of the die, in cross section, and can then be sawed into the desired lengths. For many products, the exterior of the extruded part is so highly polished in its passage through the die that it needs no further finishing.

The shape of extruded forms is limited only by the imaginations of men (and basic principles of design engineering) and the size is limited only by the power of the press and the size of the die block.

Aluminum extrusions are most frequently used when it is desired to reduce the weight or the size of the number of parts in an assembly or to achieve shapes that cannot be produced satisfactorily in any other way.

The primary producers of aluminum may, in some cases, own and operate their own extrusion plants, but much aluminum extruding today is done by independent extruders who may either buy billet from the producers or buy ingot and cast their own billet. Their presses typically have a hydraulic pressure of 500 to 2000 tons, but presses as large as 14,000 tons pressure are in operation. ■



An unlimited variety of shapes can be achieved in aluminum through the extrusion process. A billet of the metal, heated to plasticity, is pushed, under tremendous pressures, through a shaped hole in a die. The extruded metal emerges in the shape of the hole. Photographs show a 14,000 ton hydraulic extrusion press and some extruded shapes.

ALUMINUM CAN BE FORGED

IT IS PROBABLE that forging (which means to hammer metal into shape) is the most ancient of the metalworking techniques, for some metallic elements occasionaly occur in nature in such pure forms that they can be worked directly into shape by pounding. It is possible they may have been beaten into shapes before fires and furnaces could be made sufficiently hot to extract metal from native ores.

Today, aluminum is forged from aluminum alloy forging stock in four basic ways. In all of them, the stock is first heated in gas, oil, or electric induction furnaces until it has the right plasticity. The heated alloy is then either hammered or pressed into shape.

Hand or *smith forging* is, in essence, what the village smithy did, except the forging stock is turned by hand to be worked in open dies under the pounding of automatic hammers. This type of forging is used where a small quantity of parts is needed, or for operations preliminary to other types of forging operations.

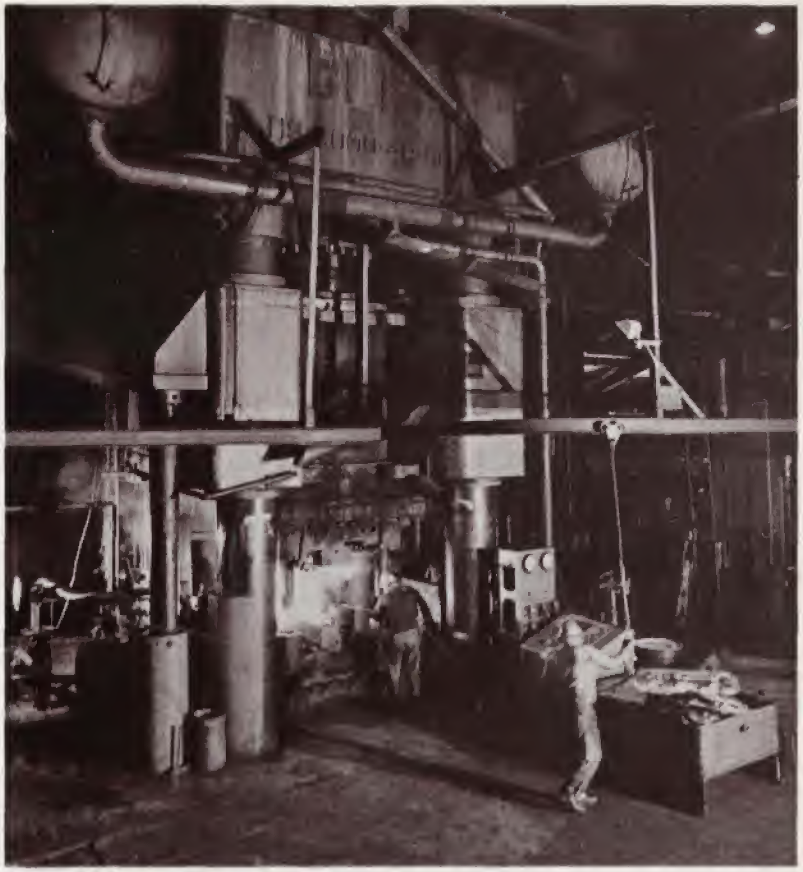
Drop forging is a quantity production method in which a drop hammer forces the forging stock into impressions in a die.

Press forging does the same thing, except that, instead of repeated blows, it exerts a fast push on the metal, forcing it rapidly into the dies at a steady rate–something like pressing putty into a crack.

Upset forging is used when it is necessary to produce something that is wider at one diameter than was the original stock.

Precision forging is the term applied to forgings that have close dimensions, or very close tolerances and draft angles. This reduces or eliminates further machining and allows accurate weight control when parts are formed in this way.

What forging does, essentially, is to move the mass of the metal to form the desired shape in such a manner that its greatest strength runs parallel to the direction of greatest strain. ■



Forging (one type of which is shown in photo above) is used to produce parts with great strength and resistance to fatigue; as in aircraft landing gear, truck wheels, connecting rods, tools and lids for pressure cookers. Some typical forged parts are shown in photograph below.

ALUMINUM CAN BE DRAWN

IF ONE TAKES a sheet of rubber and puts it over a hole and then pushes his fist down against it, the rubber depresses down into the hole. When the hand is taken away, it springs back. Aluminum doesn't; it keeps the shape of the hole it was pushed into. By this method, aluminum sheet and foil can be formed into the shapes of cups and bowls and other forms of containers, because the metal flows evenly and strongly into the die cavity, then retains its new shape.

Aluminum also can be drawn out into increasingly thinner and longer shapes and, when all the pulling is over, it keeps those shapes. Usually this is done, to form rod and tube, by pointing one end of a thin rod of aluminum, sticking it through the hole in a die, grabbing hold of the pointed end, and pulling on it. The rest of the rod follows, getting longer and thinner all the time. That is basically the process by which aluminum wire is made today.

Aluminum also can be stamped, which is a shallow drawing operation. Stamping is a press working or press forming operation in which lines, figures, decorations, shapes, etc. are impressed on smooth metal surfaces, through the use of a punch with relatively sharp outlines. Coining, embossing, blanking and pressing are all stamping operations. ■

ALUMINUM CAN BE MACHINED

ALUMINUM — in the form of rod or bar — can be turned on a lathe much like fine woods. *Rod*, incidentally, is defined as a solid, *round* piece of aluminum, ⅜-inch or more in diameter (smaller than that is called wire) and *bar* is a solid section that is square, rectangular, hexagonal or octagonal.

Aluminum is easy to machine on modern, high-speed, automatic equipment and special alloys have been developed for just this process. Literally millions of lightweight, economical machined aluminum parts are used in the appliance, machinery, electronic, architectural and transportation industries.

Basically, what machining amounts to is turning the aluminum bar or rod at high speeds (being held at one or both ends), while a sharp edged tool is pressed against it, making a controlled cut in the surface. Many intricate shapes are produced in this way under mass production conditions and at very high speeds. ■

ALUMINUM CAN BE ROLLED

WHEN ALUMINUM IS PASSED between rolls under pressure, it becomes longer and thinner in the direction in which the plate or sheet is moving. This simple fact is the foundation for the enormous variety of useful things that are made out of rolled aluminum—in the form of plate, sheet, foil, bar and structural shapes.

The process starts with specially alloyed rolling ingots, ranging in size up to 32,000 pounds, up to 26 inches in thickness, up to 14 feet in length, and up to about 72 inches in width.

These large ingots are preheated to rolling temperatures or higher in "soaking pits," thus being put in a more malleable state. When they are ready, they are lifted by crane and fed into a "breakdown or 'hot' mill" which consists of four rolls, one above the other, the middle rolls doing the actual work. The ingot, whose movements are controlled by an operator from a "pulpit" or control tower, is passed back and forth through the breakdown mill until the slab has been reduced to about one to three inches thick and many feet long. The ends are cut off square and the slab is then removed.

The slab may be further reduced in thickness on "intermediate" rolling mills to the point where it is as little as one/tenth of an inch thick.

It may then be coiled, reheated to soften it and further rolled—while cold—in additional mills, until the desired thickness of the sheet is achieved. It may be annealed again (to restore the softness of the metal lost during the rolling process) and sent as coils to customers or retained for further processing at the producer's mill, or cut into flat sheets.

Coiled sheet may be shipped to other processors who roll it to the thickness they want and then make finished products out of it. Some sheet fabricators start from scratch and buy ingot and go on from there to cast their own slabs and roll their own sheet products. Others with different needs and end-uses buy flat sheet cut to size.

Sheet may also be further rolled in special mills that reduce them to even thinner gauges, resulting finally in foil—one of the forms of aluminum with which almost everyone is personally familiar because it is in everyday use in most homes. ■

PLATE

■ Rolled aluminum plate is finding more and more applications in industry as techniques for improving its quality—and for handling it and joining it—are perfected.

Thick plate may be put in giant stretchers which pull it from each end to relieve internal stresses built up during rolling and heat treating. It may also be tested for hidden defects by ultrasonic equipment. Having passed all of its tests, it may then be sent to fabricators who weld sections of it into tanks for storing liquid gases at very low temperatures; or it may be specially processsed into battle armor for tanks, personnel and weapons carriers for the military; or used in the superstructure of both merchant and military vessels; or in the construction of railroad gondola and tank cars, and it may be fabricated into wings for advanced aircraft and into components for military and scientific space craft. ■

SHEET

■ One of the best known, and yet still exciting forms of aluminum is sheet. It is well known because it is used in so many ways that people run into everyday—as siding and roofing for homes, as panels for trucks and vans and highway trailers, as the skin of all kinds of aircraft and the hulls of pleasure boats, as awnings and venetian blinds and cooking utensils, as the basic material for beer, citrus juice and oil cans and a host of other uses in modern living.

And it is an exciting form, because it responds to so many operations quickly and easily. It can be stretched, bent, corrugated, patterned, colored, painted, plated, etched, anodized, polished, riveted, sheared, drawn, stamped, sawed, welded, soldered and brazed.

With all these working techniques, and combinations of techniques, to choose from, fabricators still have not exhausted the possibilities of this form of the metal, and perhaps they never will. ■

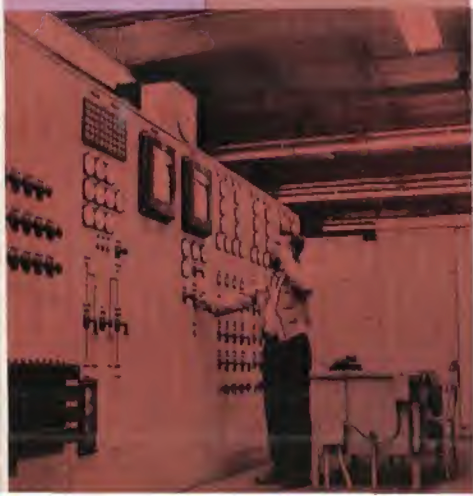
FOIL

■ Perhaps the most remarkable of all the forms of aluminum is foil, which is sheet that has been rolled very thin so that it is pliable, yet still strong. Foil is water and vapor proof, fire resistant, will not support molds or fungus growths, is impervious to insects, and can be put directly on the charcoal grill or in the oven for cooking; or used as a wrap for frozen foods, because it has good heat conductivity, reflects up to 90 percent of radiant energy and is airtight, locking in flavor and freshness.

Probably no other form of the metal touches people's lives in so many ways—as a daily kitchen necessity and as eye-catching, protective packaging for quality foods, candy, cigarets, soaps and drugs, labels for beverages;. and "heat-in" containers for pre-cooked bakery goods and prepared frozen foods. Surveys show that foil packaging automatically spells "quality" to the shopping public.

Aluminum foil is also used as a vapor and reflective barrier on insulation, in capacitors and electromagnet windings and for other industrial uses. ■

aluminum:
the metal of opportunity



PART FIVE

CAREERS IN ALUMINUM

EVERY AGE must seem exciting to the people who live in it, and doubtless this colors our own appraisal of the second half of the 20th Century. Even so, it is difficult, if not impossible, to think of any past time in which the horizons of man's world and his understanding of it have been widened and deepened so rapidly.

In this half of our century we find the earth's crust being probed more deeply than ever before, the vast unknown seven-tenths of the planet that lie under the seas and oceans are beginning to be explored, the upper atmosphere and closer interplanetary spaces have become, for the first time, accessible to man and his instruments.

In virtually every field – communications, transportation, power generation and distribution, manufacturing and metalworking techniques, agriculture, food processing and preservation and medical science—progress is being made more rapidly than at any time in history.

And, in every one of these adventures, aluminum plays a significant part. Where better, then, to take part in these ventures than by working with the metal that has helped to make them possible? Aluminum lies at the heart of nuclear reactors; forms the electronic sensors and brains of the satellites; is the bone, flesh and skin of the planet-seeking rockets; is the substance of mechanical brains and giant computers; the hull of deep sea submarines; the substance of delicate medical instruments, as well as a vital material in everyday life.

It is a *new* metal; all the other common metals have been known for thousands of years, but aluminum is so new that new things are discovered about it virtually every day. It is a *versatile* metal, with the inherent flexibility to follow man wherever his genius may lead, into technologies as yet undreamed of. It is a *plentiful* metal, equal in its quantity and world-wide distribution to meet the challenges of a rapidly growing population and of whole economies entering the era of modern industrialism for the first time.

It is an *economic* metal, because it lightens the load of the world. It takes less energy to move it, lift it, preserve it, and form it than older materials. It is a *lasting* metal; just as the gold of the Pharaohs, though changed many times in shape, being indestructible, is still in use somewhere in the world today; so the world's store of virtually indestructible aluminum grows day by day, undiminished by the inroads of time or the machinations of man. It is this age's legacy to the future, of a substance many times more valuable—but not nearly so costly—as gold.

And finally, it is an *exciting* metal—the most challenging of all the major structural materials used by man. There is not a worthwhile activity in today's industrial economy that cannot find a wider horizon and a greater opportunity through the exploitation of this new and versatile material.

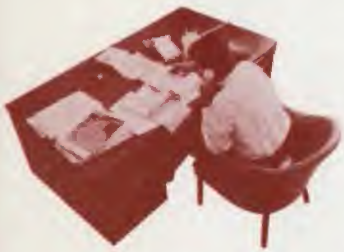
What does aluminum need of man? *Everything.*

It lies hidden in some of the most difficult and remote regions of earth. It needs skilled *geologists* to track it down, identify it, map its deposits. It needs *mining engineers* to plan how best to get out the ore, often from seemingly inaccessible mountain slopes or jungle-choked ravines.

It needs ingenious *mechanical engineers* to plan the equipment to move the ore, dry it, grind it, purify it, transport it—often over difficult terrain—in places where skilled labor is short and power supplies are virtually non-existent.

It especially needs *scientists* and *metallurgists* to explore the ultimate nature of this still largely unknown metal to the point where its manifold characteristics can be tailored to exact requirements. It needs other metallurgists to determine how best the metal can be worked and joined to itself and other materials; how it can be made stronger or more

ARCHITECTS



ORDER PROCESSORS

resistant, or made better in a myriad of ways.

It needs *chemists* and *process engineers* to find still more efficient and more economical ways to wrest the metal from its native ore—perhaps entirely new ways made possible by the advances of the nuclear age.

It needs men of vision and ingenuity to find more and better ways to adapt the metal to the needs of men—*industrial designers, product engineers* and *electrical engineers* conversant with the needs of a score of basic industries: packaging, communications, electronics, automotive, aeronautics, appliances, construction, chemical processing, power generation and distribution.

METALLURGISTS

GEOLOGISTS

In the works and plants where the ore is transformed into metal, there is need for many accomplished skills of a somewhat different nature than scientists and engineers. Producing the metal calls for a host of semi-technical skills—from the *technicians* in the quality control laboratories (where the samples of metal being produced are constantly being tested for quality) to the deft, accomplished hands that guide the control console of a huge rolling mill or a giant crane.

In truth, as with the production of anything worthwhile,, there are no unimportant jobs in the production and distribution of aluminum, and there are few technical skills—at any level — that cannot find utility with it. The processes by which aluminum is derived from its basic ore, then made into all the forms necessary to industry, are sufficiently complex and subtle that anyone engaged in them has reason to be proud of his job and the way that he does it.

MARKET ANALYSTS

The production of many forms of aluminum creates, as one might expect, a veritable storm of paperwork in its wake. So, there is need for those who are skillful with paper; *stenographers* and *secretaries* and *file clerks.*

To keep the paperwork as streamlined as possible, there is need for *systems and procedures experts* and *office managers.*

Increasingly, the language of modern business is the language of numbers and there is a need for those skilled in using numbers; *accountants, auditors, computer programmers, and market analysts.*

Once the metal has been produced, whole new ranges of skills are called for. Despite all the good things that have been said about it here, aluminum still needs to be *sold.* It is new enough that many potential users still do not know how to handle it most profitably; and, frequently, it must be sold over the obstacles of customary usage, ingrained conservatism, or allegiance to older, more traditional materials. To do this takes not just *salesmen,* but a special type of *sales engineer* who is willing to learn and apply more about aluminum than most products require of their sales representatives. In technical areas where only the expert knows the answers, the sales engineer calls upon *field engineers* who are specialists in skills like welding and joining; finishing, electrical systems; casting and forging and extruding.

To direct the efforts of the *sales engineers* into the most productive channels takes the direction of *marketing research specialists*

and *analysts*. These are, most often, people whose experience is in special fields; *food merchandising* (for aluminum packaging and aluminum household foil); *automobile manufacturing* (for engine blocks, trim, transmissions and all the other parts of automobiles made from aluminum); *aeronautics and space technology;* for these are industries quite literally built on the characteristics of aluminum; *marine architecture,* for aluminum forms the superstructure of military and merchant seagoing vessels and the hulls of pleasure boats, as well; *railroading,* for the most modern cars on the rails today are made of aluminum, and the whole system of "containerization," which cuts across all fields of

BOOKKEEPERS

the transportation of goods, is built around aluminum containers; *construction,* from family residences to modern factories to the highest skyscrapers, apartment houses and service stations, schools and hospitals and monuments; *household appliances,* including kitchen utensils, air conditioning and central

DATA PROCESSORS

heating; *chemical processing* and *petroleum production; electronics and communications;* many specialized forms of *instrumentation* for medicine, surgery, science, measurement and control; *agricultural science and economics,* for aluminum is an increasingly important material for modern farm buildings, equipment and techniques.

INDUSTRIAL DESIGNERS

ADVERTISING SPECIALISTS

In fact, it is pretty hard to think of a field of human economic enterprise where the skill of an expert would not also be of value to the aluminum industry.

In general, the aluminum industry offers the same levels of pay, the same security and fringe benefits as those offered by most other modern and progressive firms in American industry. What it offers in addition is the excitement of participating in the exploration of a great new material and the certainty that there is plenty of opportunity for advancement and promotion. It is an industry that is growing at an average of 7.4 per cent every year; doubling in size and therefore in opportunity every 10 years.

With this growth rate, the aluminum industry offers men and women an opportunity for useful and rewarding careers that is scarcely matched in any other major part of American industry. ■

PERSONNEL MANAGERS

SECRETARIES

aluminum

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aluminum

INTRODUCTION—The men who know aluminum best—the growing ranks of producers and fabricators—are fond of reciting the many ways in which the metal can be adapted to myriad end uses. At the slightest cue, they'll tell you how it can be alloyed and anodized, wrought and welded, cast and clad, and changed in any number of other ways.

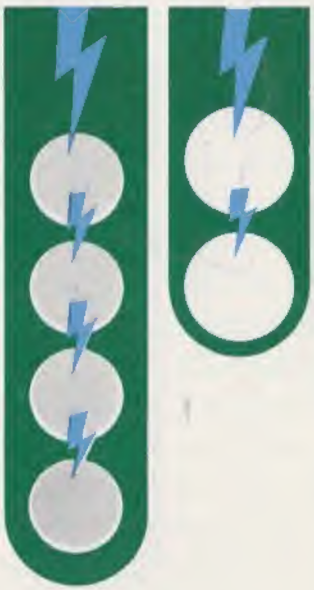
Most users, caring less for the manufacturing capabilities of aluminum, will say they like it because it's corrosion resistant, or light, or strong, or attractive, or easy to maintain. Sometimes, it's hard to believe they're all talking about the same material. If one word had to be used to explain the meteoric rise of this comparative newcomer to the world's list of essential raw materials, it would be versatility. More than anything else, versatility has placed aluminum everywhere in just a few short generations.

Aluminum made its late start not because it was scarce. On the contrary, aluminum is the most abundant metal on earth. Scoop up one handful of clay at practically any spot on earth and you will be holding some aluminum. Not in metallic form, of course, but as bauxite, the mineral from which aluminum can be made.

However, it wasn't until the 1880's that commercially feasible

Using aluminum . . .

Aluminum automatically protects itself. When aluminum is exposed to air, an extremely fine film of transparent oxide forms instantaneously and seals the surface to attack. Scratch that surface and, again instantly, another self-sealing surface forms. That's why aluminum is so easily maintained, why it seems to last forever.



Pound for pound aluminum has twice the electrical conductance of copper. This means that over a given distance an aluminum wire or cable can transmit the same electrical power while weighing half as much. That's why aluminum is the overwhelming choice for overhead electrical systems and is moving strongly into new uses in underground and building systems.

Aluminum weighs one-third as much as steel; 30 percent as much as copper; 38.4 percent as much as zinc. It makes explosive powder, dazzling fabrics, tough household foil and light armorplate for tanks. Its properties give it an amazing range of uses, with the designer's imagination seemingly setting the only limits.

processes were developed for freeing pure aluminum from its ores. Since then, aluminum has taken off to become the world's second most widely used metal. All because of its amazing versatility.

Consider the fact that aluminum can withstand the terrific pressures of the deep sea as a submarine hull and also be made into filmy tinsel. Or that it is rolled into countless miles of wrapping foil and in other forms powers rockets and makes armor plate for tanks. Or that it can be strung across the nation to carry high-voltage electricity and also serve as an attractive and durable cladding for homes and skyscrapers.

Where can you use aluminum? What's your need: lightness combined with strength, conductivity, corrosion resistance, heat reflectivity, ease of maintenance, economy, beauty? It's all there: a wide spectrum of properties and advantages to fit your special requirements. In the following pages, woven against the framework of principal applications, we hope to show you just what it is that raised aluminum from a $545-per-pound laboratory curiosity in 1852 to the ever-present workhorse it is today.

Aluminum doesn't always look like aluminum. It can be any color, almost any texture. It can be clad with vinyl or laminated with wood. It takes paints, dyes and finishes readily and won't rust out beneath a coating. Through new alloying and electrolytic anodizing processes, colors become part of the metal itself; they can't chip, flake or peel off.

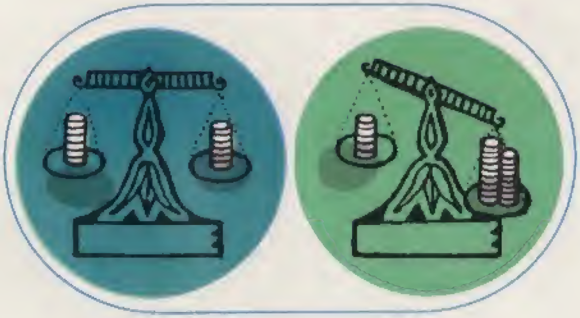
Aluminum-multiplying uses have made it one of the nation's fast growing materials. From a specialty metal used in only a few products a few decades ago, it has blossomed into the nation's second most widely used metal. In a decade (1956-1965) production of aluminum grew almost 80 percent, compared with a rise of roughly 50 percent for nonferrous metals generally and an increase of roughly 10 percent for steel production in the same span.

From precious metal to ubiquitous *metal, in less than a century,* that's aluminum's story. As a laboratory curiosity in 1852, it cost the equivalent of $545.00 a pound. It was used for jewelry and fine gifts. Then, with reduction process improvements, the price plunged. Today, it costs about the same per pound as it did in 1930, despite inflation and other price changes over the years.

CONSTRUCTION — There lives, on the other side of the Looking Glass, a White Knight quite proud of his design to "keep the Menai Bridge from rust by boiling it in wine." A novel solution for corrosion problems of Lewis Carroll's day, perhaps, but design engineers no longer ponder such desperate measures to cope with the elements.

Aluminum literally started at the top in the construction field. In 1884, a 100-ounce aluminum casting was placed atop the Washington Monument. The cap is so durable, it still stands. In the ensuing years, aluminum has made the building-construction market its largest. Why not, with a metal that doesn't rot, warp or rust, demands little maintenance, and bears finishes that don't require repainting for many years? Fashion residential siding, windows, doors, soffits, awnings, gutters, and downspouts of aluminum, put them in place, and sit back.

You may have to scrape the leaves out of the gutters once in a while if you forget to lodge an aluminum strainer where it will do the most good. But that's about all. Or take another example. Commercial livestock benefit from having an aluminum roof over their heads to repel the sun's heat. A cow gives more milk and a



First costs are not final costs, smart business men have learned. They know they can often save money by spending more at the beginning. Highway light standards, signs, railings, fences and other products can cost more when they are made of aluminum. But the money saved by drastically reducing maintenance and by sharply increasing the product's useful life can more than repay the initial outlay. Residential siding tells a similar story in repainting economies.

A home's pleasures without a home's chores is an ideal pursued by builders and house buyers alike. They look for a carefree package — one you could move into and then forget about. It may never be possible to go that far, but the ideal is brought closer by such things as factory-finished aluminum siding, aluminum windows that need no painting, and carefree storm windows that are seasonally changed by push-pull adjustments.

hen lays more eggs when aluminum keeps them comfortable. And as a result, a farmer makes more profits. From its experiences on the farm, aluminum reaped a harvest of other applications. Its superior performance as a roofing material there stimulated its adoption for other building applications, most notably residential siding, and industrial roofing and siding.

Ten years ago, you had to hunt around a bit to detect the aluminum that went into the average new home; today aluminum is all over the house, as more builders learn to capitalize on sales points like appearance, easy maintenance and lower heating and air conditioning costs. However, the major share of the residential market is accounted for by modernizations, additions, and alterations to existing dwellings. This reflects, for the most part, the homeowner's recognition that the metal will last longer and require less maintenance than the material it replaces.

More than three million homes have been clad with aluminum and the residential siding market consequently has grown from a drop in the bucket to nearly 300 million pounds annually. In the last decade alone, the use of residential aluminum siding has increased a spectacular 500 percent, receiving a tremendous

Aluminum siding with a baked-enamel finish is normally guaranteed against chipping, peeling or cracking for 15 years or more. The average home with wood siding has to be repainted about every three years. Assuming an exterior paint job cost $200, aluminum siding could save $1,000 in painting costs over a fifteen year period. Accordingly, residential siding accounts for the single largest building use of aluminum, and one of the fastest growing.

The advantages of aluminum that fit it for use in modern buildings are first, its homogeneity, weather resistance, water repellency and rust-proofness; second, its susceptibility to precision fitting of parts; and finally, the beauty of surface that aluminum affords.

Dr. Walter Gropius
Harvard School of Design

The aluminum cap of the Washington Monument was formed from a 100-ounce casting in 1884. The cap was such a novelty that it was first exhibited in New York among the displays of fashionable jewelry in Tiffany's. Today, that original casting is still the point of the monument, having withstood more than 80 years of outdoor wear without needing replacement.

boost from the development of colorful factory-applied enamel coatings that are usually guaranteed for 15 years or more.

An eastern university once made a dollar-and-cents research examination of aluminum's claims. Tests matching eight-inch aluminum clapboard siding against four other popular exterior wall materials showed that aluminum cut heating bills by more than 30 percent, painting bills by almost a third, and repair bills by 50 dollars per year. So much for the farms and suburbs. Go downtown now and look up at the buildings like a tourist. A lot of that attractive color and texture that stands out is prefabricated aluminum curtain wall. Light in weight for easier positioning and less demand upon load-bearing members, and maintenance-free for long-lasting appearance, aluminum is being put in place here to the tune of 100 million pounds each year.

The colors demand some attention in their own right. Most aluminum curtain wall is colored by an anodic process in which the color becomes part of the surface, not merely a layer that can chip away. Because of this beauty and durability, there has been

Among the more spectacular monumental structures that have called for major quantities of aluminum are the Air Force Academy complex of buildings near Colorado Springs, Colorado, and the Vehicle Assembly Building (VAB) at Merritt Island, Florida. The various structures of America's newest service academy together contain millions of pounds of aluminum, for applications ranging from exterior panels and windows to handrails and grilles (as well as handsomely modern interior furniture of anodized aluminum). The VAB, in which the moonbound Saturn V will be put together, is the largest building in the world, towering 524 feet above Merritt Island's sands and sheathed in specially-designed, aluminum ribbed siding. With the addition of aluminum duct-work and flashing, VAB uses about 4 million pounds of aluminum.

The first aluminum-clad skyscraper opened its doors in 1952. Among the engineering feats that attended its construction was the installation of metal panels at the rate of a floor a day. That record was surpassed a few years later when a 40-story building in New York was completely sheathed in aluminum in a single day.

a large growth in the use of anodized aluminum for cladding on office buildings, apartment houses and store fronts in many cities and towns.

And even where aluminum curtain walls or store fronts are not in view, you're sure to catch more than a glimpse of aluminum doors, windows and other building components doing their jobs as no other material can. Inside these buildings there's lots of aluminum spread around too, in the form of partitions, hinges, shelving, locks, latches, clothes racks and even door numbers. In most modern structures, aluminum is everywhere.

Or, leave town and hit the open highway. Aluminum can be seen all over, promoting the safe driving that has become a national cause. Along the road you'll see aluminum guard rails, lighting standards, drainage culverts, highway signs, bridge railing and light deflectors. Aluminum is used here because it resists corrosion, even under the worst outdoor conditions, and needs no protective coating.

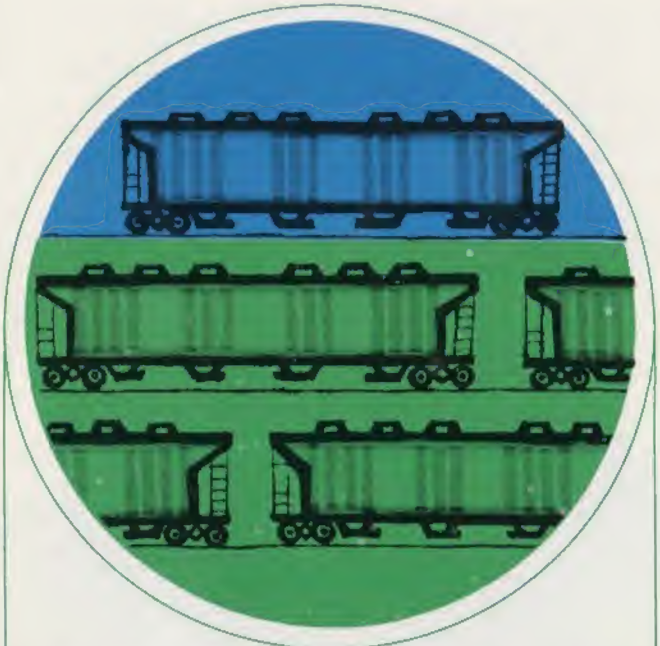
Farmers have taken advantage of the fact that aluminum roofs reflect up to 95 percent of the sun's radiant heat and result in higher livestock production. In an actual test, Iowa hog raisers housed their pigs under a variety of roofing materials for an eight week period. The results showed the pigs under aluminum roofs gained an average of 11.2 pounds more on 17.1 pounds less feed per head. Poultry and dairy and beef cattle show similar results under the protective comfort of aluminum.

The newest symbol of luxury is the family swimming pool, for which aluminum is becoming a favorite. For the low-cost above-ground pool, aluminum sheet sidewalls give rigidity and protect the plastic liner. Composite in-ground pools have concrete floors but use aluminum sidewalls which can endure the contraction and expansion caused by temperature changes and withstand the stresses of minor movements of earth backfill. And with aluminum, no matter how often it is splashed and soaked, the problem of corrosion is minimal.

TRANSPORTATION — In transportation, aluminum is confronted with industries in ferment. Ships, trains, automobiles, trucks and buses, commercial vessels are all going faster, becoming more efficient and more modern. All are demanding materials that are strong, lightweight, attractive, and easy to maintain. That's why transportation is one of aluminum's two biggest users, along with building and construction.

With the emphasis on improving passenger and cargo transportation, there is nowhere for aluminum to go but up. Take aircraft. It is calculated that every pound saved in the air frame means nine pounds saved in the power unit and other components. That means higher payloads. The aircraft manufacturers believe it; 80 percent of the dry weight of the typical aircraft is made of aluminum. The Boeing 707, for instance, lifts 50 tons of aluminum on each flight and the load would have been heavier (and the payload much lighter) if an alternate material had been used.

And so, aluminum remains the material of overwhelming choice for air frames in practically all commercial, military, personal, and business craft now being built or designed. Alumi-



The first recorded application of aluminum in railroad equipment came in 1894, when the New York, New Haven and Hartford line used aluminum seat frames in a car of special lightweight construction. The metal has played an active part in railroading ever since, helping to reduce fuel costs and permitting the carrying of more revenue-producing cargo. In 1960, the use of aluminum made possible the first 100-ton covered hopper car. The highly successful operation of that model led other major railroad companies to order production quantities.

num forgings are used for landing gear structural parts and retracting mechanisms; aluminum goes into the aircraft wheels that must carry astonishing high loads in relation to their size and weight and withstand the tremendous impact of landing. Railroads are also showing keen interest in high-capacity freight cars with increased lightweight characteristics. The reason is simple. The less deadweight a locomotive has to pull, the more revenue-producing cargo it can haul. Cut maintenance costs besides and there is just that much more profit.

Even diesel locomotives employ aluminum pistons to secure higher rotation speeds and larger combustion loads. Between the locomotive and the caboose there runs a long string of aluminum gondola, hopper and tank cars, and their number is growing, mainly because they have proven their ability to haul more at less cost, to stand up to the job, and require a minimum of care. In addition, aluminum components such as freight car doors, provide important weight savings and are easy to operate and handle.

On the passenger side of the railway business, aluminum is going into more and more rapid transit cars at an increasing rate

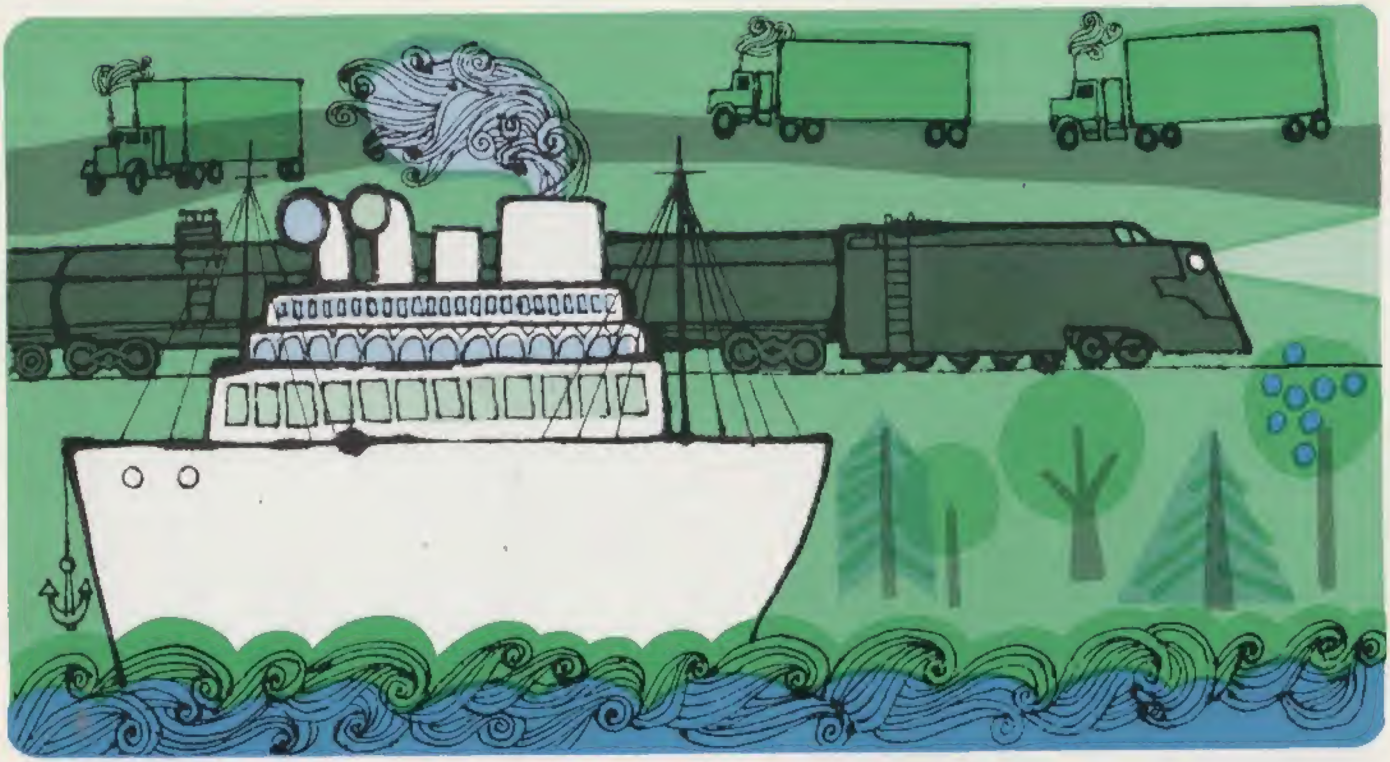
Today, aluminum is an indispensable factor in the great military and commercial fleets that fly the world's airways. An official of the National Aeronautics and Space Administration has been quoted as saying: "It is clear that our aluminum alloys not only satisfy the requirements of yesterday's 150-mile-per-hour DC-3, and of tomorrow's 1,500-mile-per-hour transports; they are the best air frame materials for these transports and for the many others that came between them in time."

Aluminum and automobiles got together early. The three-wheeled 1897 Clark boasted an aluminum crankcase. The famed Rolls Royce "Silver Ghost," with its engine parts and body of aluminum, is still in excellent condition after more than 50 years and 500,000 miles. Collectors still sigh over the 1930 Duesenburg and its hand-fashioned aluminum body.

because the metal's light weight fits in with the trend toward ultra-high speed train service. Attractiveness can be added to aluminum's other features here. External cladding, doors, and interiors are all getting the aluminum treatment.

If you make a business of transporting cargo or passengers by sea, you know there's a Plimsoll line on the side of your vessels that determines how much you can carry. It's the same story here; save deadweight and add cargo. The lesson was driven home when the S.S. United States was launched. The giant liner carried over 2,000 tons of aluminum in its superstructure and other components, thereby cutting its total displacement by 4,000 tons. Weight saving wasn't the only factor; aluminum's resistance to salt water corrosion was already well-known.

Commercial fishing boats make similar use of aluminum, and speedy personnel boats with aluminum hulls service offshore oil wells more efficiently than ever before. Door-to-door cargo containers are another important and growing use of aluminum. Commercial highway vehicles represent another important area



The metal of motion. A train needs fast starts, economical operation and easier stops: use aluminum to cut weight, reduce inertia and momentum. A ship needs a low center of gravity to retain stability in motion: use aluminum on superstructures and high-up gear and fixtures. A trucker needs as many paying pounds of cargo as he can fit into highway load limits: he uses aluminum for many major trailer components, his tractor cab chassis, engine components and wheels.

for aluminum, particularly in truck and trailer applications where weight, strength, and maintenance savings are essential.

Large diesel engines for line haul tractors use aluminum extensively, notably castings for oil pans and numerous other engine parts. And don't forget the forged disc wheels, which, being truly round and perfectly balanced, provide a smoother ride, extend tire mileage, and better heat dissipation. Automatic transmission systems remain the largest single use of aluminum in the passenger car, but other uses abound, including attractive interior and exterior trim, grilles, headlamp bezels, moldings and seat shields.

There are also aluminum bearings, pistons, blocks and cylinder heads for racing cars, and air-cooled aluminum engines. Cast and forged aluminum wheels in sporty design concepts are increasingly popular too, and aluminum's heat dissipation rate carries it into brake drums. Automobile air conditioning is a growing use for aluminum. Aluminum radiators, already in one American-built sports car, are under development for high-volume application.

Underwater exploration has enlisted the service of aluminum for hulls capable of withstanding the tremendous pressures far below the ocean's surface. In addition to man-carrying vehicles, remote-control research devices and deep sea housing for instruments and photographic equipment rely on the strength, buoyancy and corrosion resistance of aluminum.

One new kind of fishing boat is an 86-foot, all-aluminum trawler that promises higher profits for fishermen. Fast enough to reach distant fishing grounds, big and light enough to carry 38 more tons of fish than a similar sized boat of another material, it can also save about $3000 a year in maintenance costs, because it needs no painting.

ELECTRICAL — There must be, within the aluminum industry and the nation's electric utilities, a strong temptation to form a mutual admiration society. The two industries grew up together and today play large interchangeable roles of producer and consumer. Just five years after Thomas A. Edison started his rudimentary electric power station — the first of its kind in the world — down on New York's Pearl Street in 1881, Charles Martin Hall emerged from a backyard woodshed-turned makeshift laboratory with a workable electrolytic process for making aluminum.

Hall's accomplishment was at once the birth of a large industry and the creation of a potentially huge customer for the utilities that were soon to power the nation. But that is only part of the story. When the Pearl Street plant was placed in operation, copper was one of the chief components of the generators, motors, light sockets, bulbs, junction boxes, safety fuses, underground conductors, and related paraphernalia that the Wizard of Menlo Park devised for the distribution system.

Aluminum was an $11.33 per pound novelty then, but because of its high conductivity, the potential importance of aluminum in these applications was recognized from the start. In 1897 engi-

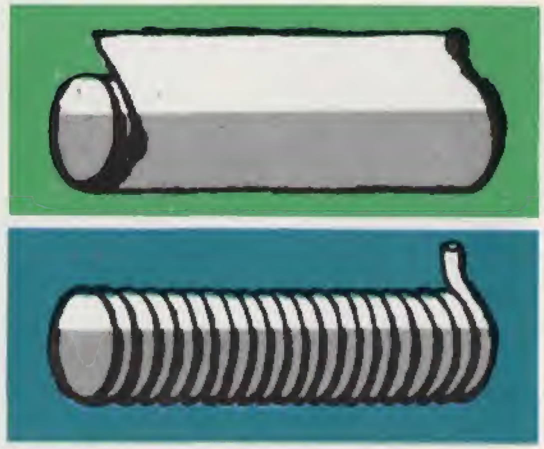
A promising market for aluminum lies in the increasing need and desire of utility companies to carry their lines underground. Real Estate developers in many sections of the country advertise prominently the fact that their tracts are free of visible wire. Potential emergencies ranging from windstorms to warfare call for better protection of current-carrying lines. Solution: go beneath the surface. The growing trend to underground distribution is paralleled by a growing trend to aluminum for this use.

neers strung up a half-mile length of solid No. 11 gage aluminum wire to replace a similar length of copper telephone wire in an area around the Chicago stockyards where locomotive gases created a constant corrosion problem. At the time, the aluminum cost five times as much, but performed so well it was considered a good investment.

Since then, the cost of aluminum has sunk below copper and its electrical use has become commonplace. In fact, the electrical industry is increasing its use of aluminum more rapidly than any other segment of our economy. It is as an electrical conductor that aluminum has made its most impressive gains, and with good reason. Aluminum's ductility makes for easy drawings into wire and its weight is but a third of copper's. Pound, for pound, it is twice as conductive. And, of course, it is non corrodible.

These advantages, plus a favorable strength-to-weight ratio, have given aluminum an overwhelmingly dominant — more than 90 percent — share of the nation's rapidly expanding overhead transmission and distribution system. While most of this is in the form of ACSR (aluminum cable, steel reinforced), cable with aluminum alloy replacing steel as a strengthening core is begin-

Anyone who tinkered with radio sets "back when" is familiar with the cylindrical aluminum condenser cans and tube covers that were an early application of aluminum in the electronics industry. Aluminum foil has long been the material employed for condenser "plates" or windings, which represents a significant use of aluminum in this industry. Today's proliferating electronic devices — ranging from esoteric laboratory equipment to home television sets — depend heavily upon aluminum for panels, housings, chassis, bezels and other components. Aluminum's fabricating versatility and its variety of color and texture finishes are highly prized advantages.



An ingenious development of the aluminum industry promises to change the standard material used in winding electrical coils. Traditionally of copper wire, coils are more and more being wound from aluminum strip conductor, from very thin foil to fairly thick sheet. A layer of a coil, historically a number of turns of wire, side by side, is now replaced by the aluminum strip, which is the full width of the coil. Both material and production economies result. Aluminum strip is now emerging as a standard for the coils of electrical distribution transformers (which grace pole tops along suburban streets), and is expected to find wide use in many other devices.

ning to come into its own. Conductor for overhead systems is almost exclusively aluminum because its lightness and strength permit longer spans between supporting structures, and now even the supporting structures are made of aluminum.

Because aluminum resists rust, transmission line towers and substations of aluminum pay their own way in areas where other towers might require frequent painting. While aluminum has successfully swept the overhead transmission field, it's going underground. For reasons of safety and attractiveness, many communities are switching to underground residential distribution (URD) systems, and aluminum is riding the crest of the wave. Its relatively low cost and easy availability is giving aluminum a big push in this area.

In another major trend, aluminum conductor is showing up more in the form of building wire, which distributes electricity throughout homes and other structures. Because aluminum building wire is lighter, more malleable, less expensive and more readily available than other conductors, its use by electrical con-

tractors is growing by great strides. And the conduit that carries those wires is more likely than ever to be aluminum. Less expensive to install because of its light weight and more economical in the long run because of its freedom from maintenance, aluminum has nudged traditional metals aside for a large portion of conduit applications.

In both conducting and non-conducting applications, electrical use of aluminum is as far-reaching as the electrical industry itself. The housings and many components of communications and electronic equipment are often made with aluminum. Lighting fixtures in homes, office buildings, factories and along the roadside are commonly aluminum. It's almost certain that the base of every lightbulb in your home is made of aluminum.

Every common type of electrical equipment — including TV, radio, phonograph, telephone and tape recorder — contains aluminum components. When aluminum and electricity first got together, it was the beginning of a good connection that is still growing in power.

More than 90 percent of the overhead transmission conductor that carries electrical power throughout the nation is made of aluminum, and with good reason. The electrical industry knows that the light weight of aluminum conductor makes possible a wider and more economical spacing of supporting towers. And pound for pound, aluminum conducts better than other metals. There is also a growing interest in aluminum towers or tower components where the light metal's special virtues are of economic advantage: corrosion resistance for extremely adverse environments, and lightness for easy transport — sometimes of an entire tower by helicopter — into inaccessible areas.

One way to tell the age of a light bulb is to look at its base: the part that screws into the socket. It it's made of brass, chances are good, for whatever it's worth, that you've got an antique on your hands. Brass once dominated the application. Today, practically all light bulbs, incandescent or fluorescent, have aluminum bases or end caps. First developed in the 1940's, aluminum lamp bases swept the field by virtue of their low cost, electrical conductivity, good formability and adequate strength.

CONTAINERS AND PACKAGING— Aluminum shows its bright face most frequently in the billions of food, beverage and other product packages that are pulled from market shelves each year by American consumers. In just a few years, aluminum has plunged deep into the ocean of container and packaging applications to become established as one of the major materials that people instinctively think of when considering packaging possibilities.

And the possibilities are numerous: all-aluminum cans for beer, soft drinks, pet foods, meats and other processed products; easy-open aluminum tops for beverage, snack and food cans; semi-rigid, oven-heatable containers for frozen, baked and precooked foods; twist-off bottle caps; aluminum tubes for toothpaste, paints and other squeezable goods; laminated foil for packaging tobacco, candy and gum, among other confectionery items; composite aluminum and paperboard containers for frozen concentrates, motor oil, and shortening; and, of course—the homemaker's best friend — household aluminum foil.

Aluminum's versatility is demonstrated by the amazing case of the easy-open can. What was needed to make the breakthrough, obviously, was a material that would be tough enough to protect the product, yet flexible enough to be lifted open by the most fragile housewife. Introduced in 1961, easy-open tops had captured 75 percent of the canned beer market by the mid 1960's. Now all manner of products come with handy aluminum tear tops. The most modern can opener is a fore-finger and thumb.

Cookout time is foil time. Outdoor chefs line their fire-boxes with foil to protect it and to reflect heat up to the food on the grill. Then they use a foil lining on the hood to reflect the heat back down again. They wrap their baking potatoes and roasting ears in foil to spread the heat and seal in moisture, and warm their rolls in foil clusters. In all these things, they are using aluminum's conductivity, reflectivity and toughness, served to them in handy packages.

Aluminum lids already top most cans containing beer and soft drinks and the all-aluminum can has been gaining rapidly. Also available are small aluminum kegs that serve draft beer directly from the refrigerator. How was aluminum able to cut a wide swath through a market long dominated by other materials?

Review the long list of the metal's special properties. Because it is easy to form and can undergo certain operations not feasible with steel, aluminum glides through the impact, drawing and ironing processes used for making easy-open, seamless cans. Aluminum's thermal conductivity means easier heating or chilling of the product inside the container. Because it is nontoxic, odorless, and tasteless, it performs well as a package for foods, beverages, and pharmaceuticals. For maximum protection, aluminum is an effective barrier to the passage of light, air, moisture, grease, and inert gases.

Add to these attributes the facts that the metal is easily decorated to achieve the kind of attention-getting appearance that makes every package an appealing advertisement for its contents,

Perhaps the most familiar aluminum "package" is a hand-crafted model that can be fashioned in the home to wrap irregular shapes for storage or cooking. How many billions of these instant containers have been made since household aluminum foil in rolls was introduced after World War II can never be calculated. However, it is known that household foil accounts for over 100 million pounds a year, an average of four packages per family.

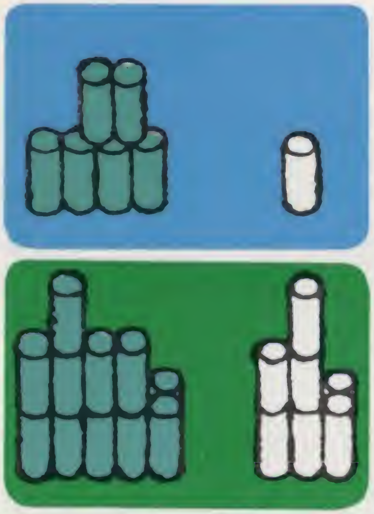
Rigid-foil containers can be cooked in and served from and, for the resourceful, used over and over for a variety of purposes. They're handy for holding a wet paint brush, melting butter, placing under flower pots, collecting odds and ends, and all manner of uses where you want something that won't leak, corrode or shred.

and that aluminum's lighter weight reduces shipping and handling costs for packers and dealers. The result? Widening use by manufacturers and processors of aluminum cans and other packages.

When one major meat packing concern introduced an easy-opening all-aluminum can with a colorful rotogravure-printed foil label, it saw sales of the product go up by 30 percent. Convinced of the selling effectiveness of the container, the company quickly adapted it to three more lines of meat products.

Another company switched to an easy-opening all-aluminum can for its frozen chopped chicken livers. Almost overnight, sales jumped by 500 percent. Another important event in the packaging world was the development of aluminum caps and closures for bottles.

These handy tops either screw, flip or tear off a bottle without the use of an opener, and are being used increasingly for bottles and jars containing beer, soft drinks, dairy products, foods pharmaceuticals and chemicals. Most feature the ability to reclose



Aluminum's use in cans is growing fast, and it has a lot of room to grow. As recently as 1957, virtually no aluminum was used by canners. In less than a decade, the great majority of beer-cans were converted to aluminum tear-tops. Then the easy-open tops began growing rapidly in soft drink and processed food cans. And in the mid-1960's, the all-aluminum can began to catch on widely as several major breweries decided to put their product in these lightweight, quick-chilling containers.

Air, moisture and light can be bad enemies and tough to defeat. They can cause soggy cereals and no-fizz seltzers. They can weaken or change the flavors a food manufacturer so carefully blends into his products. Aluminum foil can repel these enemies, protecting freshness. It performs this task as packets and pouches for seltzer and tobacco, as inner liners for breakfast foods and cookies, as laminate barriers in juice cans and frozen biscuit rolls. Wherever air-tightness and light-tightness are needed, aluminum foil stands ready.

once being opened. To produce the foil that has practically revolutionized the modus operandi in American kitchens, series of rolling operations brings aluminum down to a form thin enough to be handled like wrapping paper, while retaining the benefits of all the metal's other properties.

The variety of uses to which aluminum foil has been put is as limitless as human ingenuity. They range from such obvious uses as wrapping foods for refrigeration through lining ovens and outdoor grills, enclosing meats before cooking, grilling cheese sandwiches under an electric iron, and protecting silverware, paint brushes, and tools.

Campers can improvise entire cooking ensembles out of aluminum foil, and children can twist the foil into all sorts of animal shapes, or into small boat hulls that can use seltzer tablets for propulsion.

In 1898, the fledgling aluminum industry took heart when it received its first order from Ball Brothers of Muncie, Indiana. The order called for aluminum covers, to be used in sealing the company's famed Mason jars. Home canning is no longer as common a practice as it used to be, but aluminum had made its way into a most important application. More than one billion aluminum closures for food products are in use today. In addition, tamper-proof aluminum closures have become increasingly popular for aerosol cans, ridiculed 20 years ago as mere "bug bombs," but now used for everything from paints and shaving cream to the $145-million-a-year hair spray market.

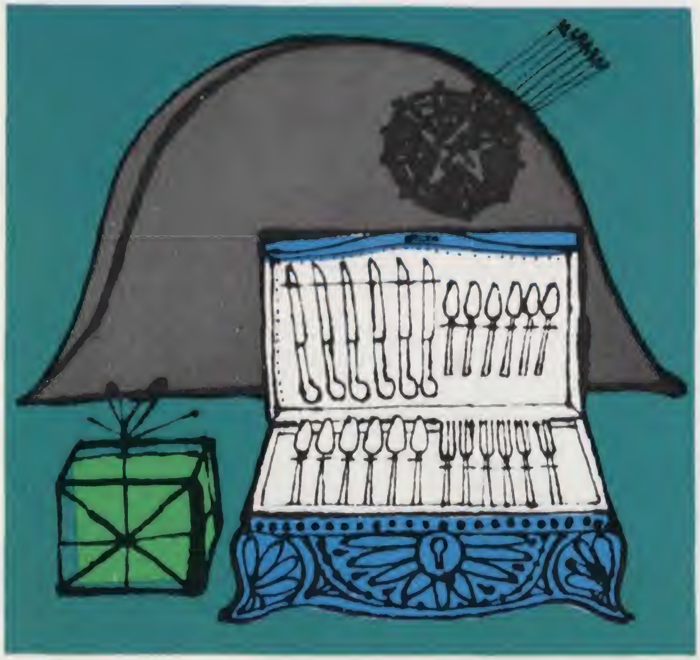
One-fifth of a second. That is the magic statistic motivating the men who design packages for supermarket shelves. It is the amount of time, according to a Purdue University study, that the average housewife gives to each package in her flight past the 8,000 or so items usually available. How to grab her attention as she whizzes by, that's the challenge. An answer: bright, exciting colors and designs, highlighted in color print and color TV advertising to boost the recognizability of what she sees on the shelf. The fact that aluminum can readily be printed by high-speed, full-color lithography (lending its own brightness as a free extra color) makes it increasingly popular to designers engaged in this contest for attention.

CONSUMER DURABLES—"Who is the potter, pray?" asked Omar Khayam back in the 12th Century. Claymakers and ironmongers then—*aluminum fabricators now.* It has been estimated that more than 70 percent of all non-electric metal cookware sold in the mid-1960's was aluminum.

The popularity of aluminum cookware with non-stick coatings lent impetus to the push but essentially it is the metal's high heat conductivity, easy cleaning and light weight that have made it the overwhelming kitchen favorite. Because of its even conductivity, aluminum cookware requires less water and lower temperatures, and it stops the cooking process immediately after the heat is turned off, a factor that means less sticking of food.

Utensils are but a part, a large part to be sure, of aluminum's contribution to the flood of products from the cornucopia that is the consumer durable goods industry. Others? Pleasure boats and water tumblers, lawnmowers and hair dryers, air conditioners and window fans for summer, portable electric heaters for winter, and refrigerators for the year 'round.

The list of products is endless, even though aluminum wasn't produced commercially until late in the 19th century. (A hun-



Long before it became generally available, aluminum was a popular material for precious gifts. France's Napoleon III ordered a set of aluminum knives and forks; gold and silver were adequate for ordinary callers, he thought, but special guests merited something more unusual. Among the gifts that a wealthy 19th century suitor showered on his beloved was a pair of aluminum-mounted opera glasses.

One of the oldest applications for aluminum is still flourishing today. Some 60 years ago, an aluminum salesman tried to persuade a manufacturer of teakettles to switch from cast iron to the new metal. He borrowed a technician from the manufacturer and had him turn out a sample. The manufacturer was convinced, and although he refused to change his own operations, he offered to sell 2,000 of the kettles if someone else would supply them. Someone else did, and thus came aluminum's first penetration into household utensils. Aluminum now takes over one-half of the cookware market.

dred years ago, Napoleon III couldn't find enough aluminum around from which to fashion armor for his armies, but he was able to get enough to provide his special guests with aluminum knives and forks.) Aluminum's popularity in consumer goods can be attributed to several factors. The manufacturer likes the metal's workability, which to him spells economy in production and freedom of design.

The consumer is drawn by its attractiveness and the knowledge that it will retain that appearance with a minimum of care. Don't forget weight, or rather the lack of it. Who wants to cart heavy lawn furniture about, or push an unnecessarily weighty lawnmower up a grass knoll, or lug heavy vacuum cleaners up staircases? Light weight is important in many of life's little things too. Things like tumblers, buttons, pens, wastebaskets, ash trays, lamps, cigarette lighters and clocks, all of which often use aluminum.

Leisure time — and there's more of that now than ever — is the time when aluminum goes to work. Sedentary types are often supported in their activities by aluminum lawn chairs or hammocks –lightweight but sturdy. For those who can't sit still, there

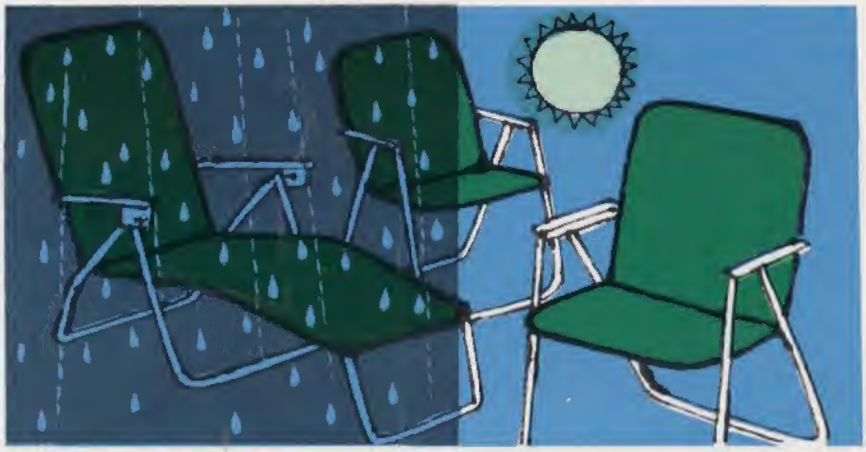
Home air conditioners, like the ancient god Janus, face both ways. The part that faces inside the room must be handsome enough to qualify as acceptable furniture. The part that hangs outside must withstand extremes of temperature. Rust-free aluminum has proved itself in every sort of climate, with vinyl-clad and prepainted aluminum especially effective.

is a whole world of do-it-yourself waiting in the garage or workshop. Aluminum reduces the workload in power tools and is available in many forms — tubes, sheet, extruded parts, nails, screws and bolts — ready to be converted into something useful or decorative.

There is, of course, the man who prefers to take his leisure to water, where more than half the pleasure craft he will see are made of aluminum. The metal comes highly recommended from experienced boatsmen for both salt and fresh water use. Aluminum hulls need little maintenance, cut weight and power requirements, and preserve high resale value. Especially significant is the demand for aluminum in motive equipment. Aluminum outboard motors resist the ravages of water, reduce a boat's total weight and improve its weight distribution. Heave to and drop the anchor. Then lower a line from an aluminum reel and prepare to fill an aluminum creel, but be careful when reeling in not to overturn the aluminum bait bucket or tackle box standing by.

Not your cup of tea? Aluminum is persistent. Get a set of

The day of the steamer trunk has passed, along with the omnipresent porter, and people boast not of how much they took along, but of how much they were able to do without. Aluminum helps. Today's tourist packs his clothing in aluminum luggage. He carries aluminum-cased binoculars. He records his adventures with an aluminum-bodied camera.



Some of the most elegant furniture in America uses aluminum sheet, tube and extrusions, often in combination with other materials. Highly workable aluminum lends itself particularly well to the construction of modular units, such as kitchen cabinets, room dividers and bookshelves. Its greatest use in the furniture market, though, comes outside the home — just outside. With people spending more time on lawn and patio, aluminum has met the need for bright, colorful pieces that can be moved easily from one place to another and left out in all kinds of weather.

Today's manufacturers of musical instruments use aluminum in applications ranging from xylophone vibrating bars to organ keyboard panels. Aluminum alloy castings can cut the weight of a piano plate by as much as 60 percent, to the infinite relief of moving men. Most grateful of all must be the men and boys in marching bands, thumping away at huge bass drums framed in aluminum.

aluminum-shafted golf clubs, deposit them in an aluminum caddy cart, and head for the first tee. Or stage a cookout with aluminum barbecue equipment and the help of aluminum foil. Not the outdoor type? There are billiard cues made from swaged aluminum, color anodized to harmonize with any interior, waiting in the rack.

Tired of standing, you say? There's a setting of aluminum bridge tables and chairs waiting for a fourth — or go back to the aluminum-framed hammock and try again tomorrow. Perhaps the sweetest leisure of all comes on holidays and other special occasions. Aluminum tinsel makes holidays even brighter, and many a Christmas tree is made of aluminum, a glittering greeting for any Santa.

Almost anything that's nice to give or receive on any occasion is made with aluminum, whether it be kitchenware, luggage, bicycles, toys, cameras, umbrellas or skis. Or refrigerators and dishwashers, if you're in a more generous mood. One thing's for sure — if a gift is made of aluminum, it will last a long, long time.

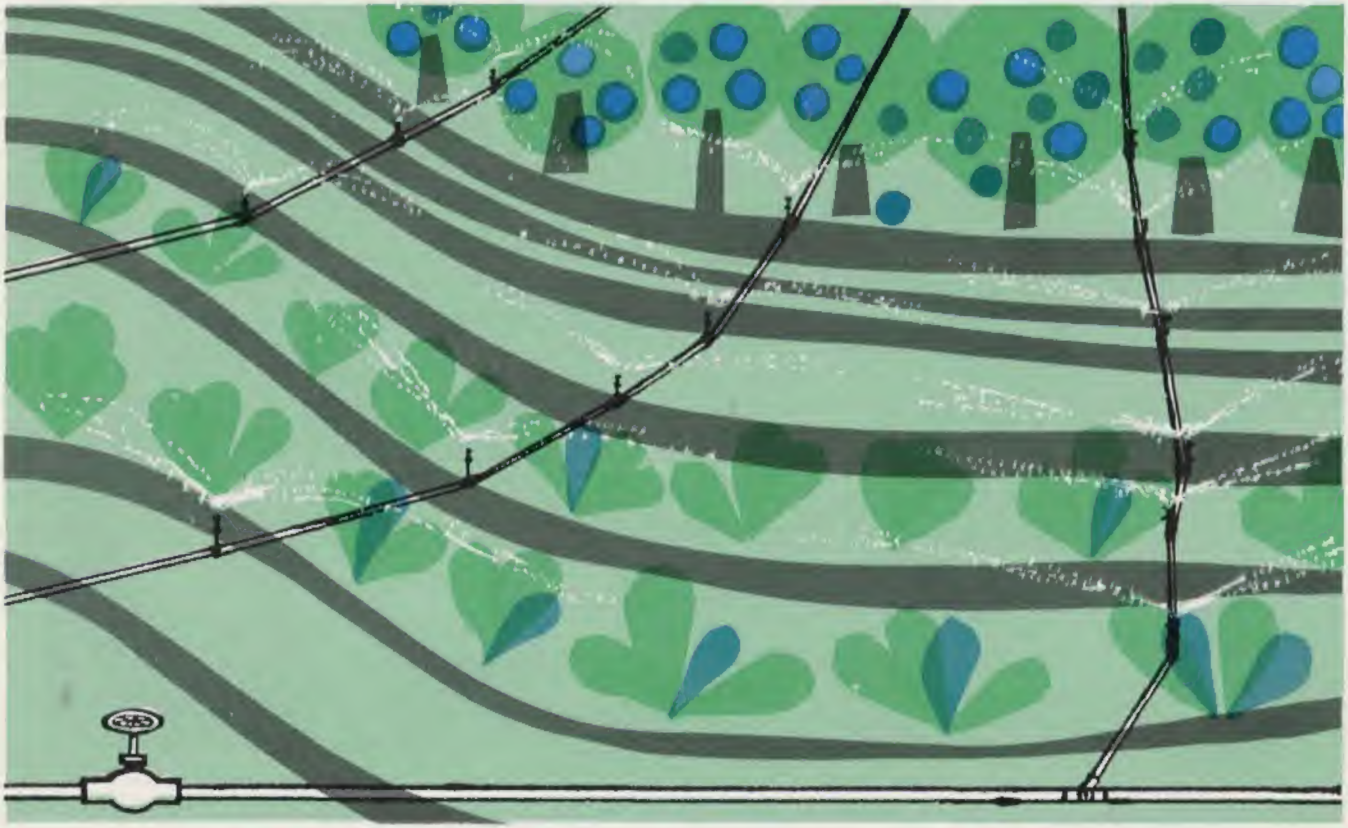
Aluminum loves water, which makes it great for boats. More than half of today's pleasure craft use aluminum hulls and the metal is popular for sailing masts and a host of other sea uses. For the working boatman, it is popular as fishing boat material: it needs very little maintenance, runs light and economically, is tough and can be washed down easily.

MACHINERY AND EQUIPMENT—The idea of making equipment and machinery from aluminum dates officially to a surveyor's transit produced in 1876. It was nice and light to carry around and its corrosion resistance became increasingly evident as it continued outdoor service for 50 years. Now, there are a multitude of uses.

There are housing and end covers for pumps; pistons, connecting rods, bearings, and bushings for compressors; valves for hydraulic circuits; forgings, castings, and parts for computers; fans and blowers; tanks, vessels, and piping for the chemical processing industries, irrigation systems, and many more.

Lightness makes for less effort to get machinery parts into motion from a dead stop, as in conveyor systems or textile machinery; corrosion resistance cinches the deal when these parts are for pumps and compressors used in contaminating environments or to move corrosive fluids. Lightness plus strength produces economical scaffolding and ladders with easy assembly and dismantling. Corrosion resistance spells savings on maintenance.

In drilling for oil, the petroleum industry is beginning to dis-



Aluminum pipe is almost the only kind ever used for portable irrigation systems, because it is light, durable and resists corrosion. Farmers move these systems by hand or machine from one part of their fields to another to increase the yield of their crops and grazing land. The use of aluminum irrigation systems is common in arid parts of the country, and is being used increasingly during dry spells in humid areas to provide water where and when it is needed.

cover that aluminum drill pipe can be more effective than other pipe because of its lightness. The light weight permits longer strings of pipe laid with standard surface equipment, lowers transportation costs and reduces crew requirements — all of which lead to long-run economies. In offshore drilling, the light weight and flexibility of aluminum pipe are especially valued.

Special qualities put aluminum into special services. Textile firms require a metal that will not damage or discolor fabrics, yet one which is light enough to have low inertia for use on reciprocating parts of weaving equipment. Food processors want a nontoxic material that will not alter food flavor. Chemical processors need a metal that will resist powerful bleaches and solvents, and tire manufacturers require a metal that has a high rate of thermal conductivity to assist in the rapid transfer of heat in tire molding. In plants where cleanliness is important or where the environment is corrosive, walkways and stairs treads need to be made of an easy-to-maintain material.

Always ready to move into new areas, aluminum is playing a major role in the modern science of cryogenics, the production and storage of liquefied gases for rocket fuel and other space-age

Aluminum can handle sulfuric acid solutions of over 98 percent concentration. In addition, it resists attack by fuming nitric acid solutions. It is not attacked by elemental sulfur, and so sees wide use in vats, conveyor structures and architectural applications in sulfur environments. A dramatic demonstration of this property took place recently in Montana, where a well drilling contractor used aluminum to cut the weight of his drill pipe by half and boost his rig capacity from 5,500 to 7,000 feet. At a little over 2,000 feet, they struck a layer of sulfurous gas. Silver coins in the drillers' pockets were blackened by the gas, while the aluminum was unaffected.

A variety of aluminum powders and particles sees wide usage. Perhaps the most familiar is as a pigment for paints, both in natural aluminum and other colors, widely used for more than four decades. There are aluminum paints for metal, masonry and interior wood; weather-exposed wood; nonweathering surfaces heated to 600 degrees Fahrenheit; metal heated above 600 degrees Fahrenheit; water-immersed metals; and other material.

Early in its history, aluminum got a major boost from the industry whose chief competitor it was to become. Steel producers discovered that aluminum would draw off oxygen to free steel ingot from blow holes. It took only a few ounces to quiet a ton of molten steel, but even ounces counted for much in those days. Its use for this purpose continues.

uses. Indeed, the metal seems to have been made for the super-cold world. Take a particular aluminum alloy, cool it to minus 400 degrees Fahrenheit or lower, and what happens? This alloy's tensile strength and ductility actually increase where some other metals would become extremely brittle. And so, when tanks are made for safely storing and transporting liquefied gas, they are often made of aluminum sheet or plate.

Aluminum's cryogenic strength, plus its high thermal conductivity, has made it common in heat exchanger equipment in which heat must be transferred from one substance to another. Thus, in one heat exchanger, 200 miles of aluminum tubing was placed inside a shell-oven 80 feet long. Aluminum was chosen over copper because it was economical and saved 100 tons in weight while handling the basic tasks of withstanding operating pressures of 600 pounds per square inch at temperatures below minus 200 degrees Fahrenheit.

Any hydraulic engineer will tell you that liquid flowing through a tube can build up friction severe enough to resist its passage significantly. Conventional aluminum tubular products are inherently smooth-surfaced, with approximately the same friction factor as smooth-drawn tube of other materials. Aluminum thus becomes an economical and effective material for the process and petroleum industries, in heat exchanger tube, piping and in many other areas.

DEFENSE—"All delays are dangerous in war," said poet John Dryden back in the Seventeenth Century. That applies today more than ever. The world has moved into a new era of warfare in which the slow advance of great armies has been replaced by the brush fire war, and many forms that guerilla warfare takes.

For the United States, with her globe-girdling responsibilities, there's a paramount need for mobility of her fighting forces and the weapons of war, without sacrifice of fire power or armor. This need has created a wide range of opportunities for aluminum that stretches from mess kits to missiles and misses nothing in between.

Ballistic armor plate made of new high strength aluminum alloys stops shells while increasing the speed and maneuverability of tanks and other military vehicles. Aluminum pontoons and bridges, easy to carry to location and equally easy to set up, convey military personnel and mechanical cavalry across bar-

A tank has to go where the action is to do any good. New designs employing aluminum armor plate provide a tough fighting instrument that's still light enough for fast, pin-point air transport.

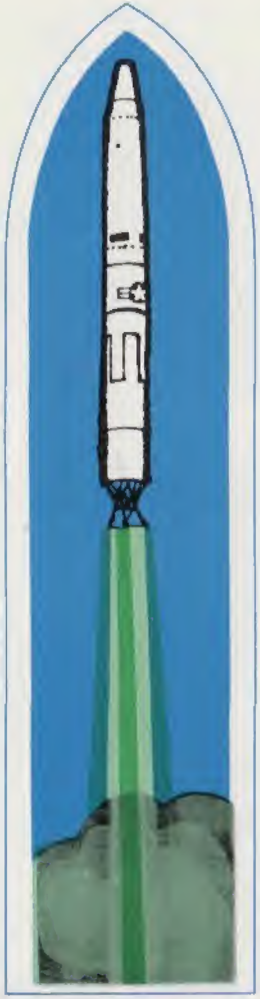
Mobile fighting forces need not stop at water's edge, or at the rim of a crevice. A scissors-like rig can move up to the spot and extend a sturdy track for the army to roll across. Aluminum is light enough to be moved into position easily, yet strong enough to handle the weight of a rolling armored unit.

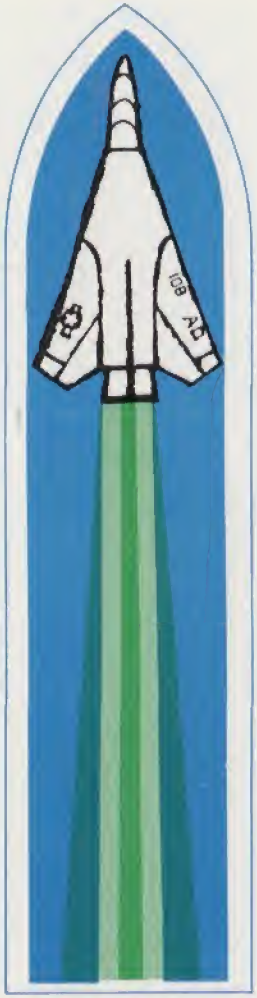
riers, and they come down just as easily for quick transport to another point where they are needed. Heavy artillery travels by air now and every pound of weight that can be saved becomes essential.

Thanks to aluminum, the M-102 lightweight howitzer can bring its 105-mm firepower to the battlefield within minutes of an air drop. Before the end of the 1960's, the defense establishment will have an all-aluminum troop carrier, the fan-jet C-5A, that will be able to carry more than 500 armed troops or a hold full of weapons and vehicles at 550 miles per hour. Ten of these 350-ton aircraft could have handled the whole job during the Berlin Airlift.

Speed is an essential with the naval arm as it is with air and ground forces, and the Navy isn't passing up the opportunities

Rockets and missiles use aluminum for everything from fuel to structural elements. The *Titan ICBM,* for instance, carries aloft eight tons of aluminum in its air-frame and fuel propellant and oxidizer tanks. Every Polaris missile takes 4,000 pounds of aluminum. Aluminum forgings for the Navy's Bullpup air-to-surface missile are fabricated into "instant" liquid rocket engines that can be fueled and then stored until needed.





Since the end of World War II, almost all the services high-performance aircraft have been built of high-strength aluminum alloys. Special treating and fabricating techniques made possible the development of the F-111. Aluminum goes into the major structural components of the OV-10-A counter-insurgency aircraft. The versatile helicopter is almost all aluminum in construction.

that aluminum provides. There are more than 3½ million pounds of aluminum on the nuclear-powered carrier Enterprise, primarily in the elevators that whisk combat aircraft quickly to her flight deck. Navy hydrofoils, gunboats, trailer ships and crew boats with aluminum hulls have more speed, and many other Navy fighting ships employ aluminum to offset the added weight of the complicated electronic gear they must now carry above decks.

Back on land, newly-developed aluminum landing mats permit troops and equipment to be flown into otherwise inaccessible areas. Aluminum goes into the construction of hangars, aircraft maintenance docks, and other support structures. In its military applications, aluminum has all the attributes of a good soldier — it's tough, adaptable and reliable.

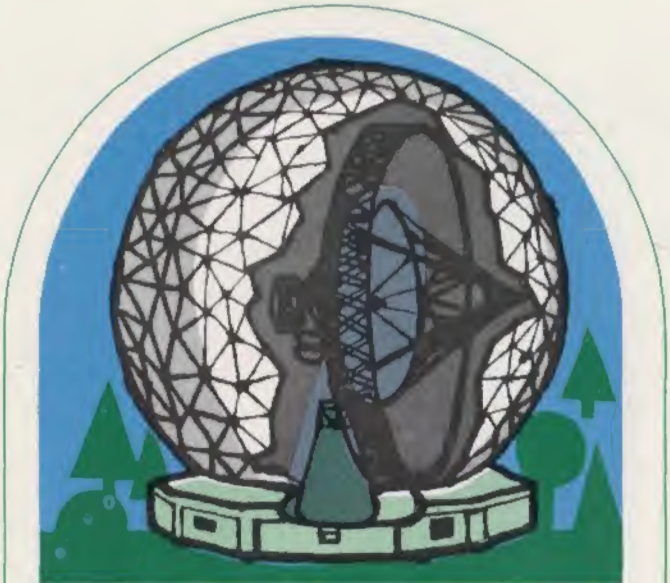
During World War II, the enemy was quick to recognize the vital role of aluminum in the American military effort. In 1942, eight specially-trained saboteurs were landed by Nazi U-boat on the coasts of Long Island and Florida. Only the quick action of the FBI in rounding up the agents kept them from carrying out their deadly assignment — to cripple much of America's defense capability by destroying aluminum-producing plants in New York, Tennessee, Illinois, Alabama and Washington.

As early as 1892, the French were ordering torpedo boats made of aluminum. During the Spanish-American War, Theodore Roosevelt carried an aluminum canteen at his side, while his cavalrymen tethered their horses to aluminum picket pins and his infantrymen pegged their tents to aluminum stakes. It was not until World War I, however, that aluminum came into its own as an important military material.

AEROSPACE — Few demands have challenged aluminum as sharply as the needs of aerospace, and few have drawn as effective a response. Not that there wasn't plenty of preparation; aluminum's experience in the aircraft industry had set the stage. Besides, aluminum's future beyond the earth's pull was foretold before Hall developed his process for extracting it economically. Jules Verne selected aluminum for his imaginary space vehicle in From The Earth to the Moon, published in 1865.

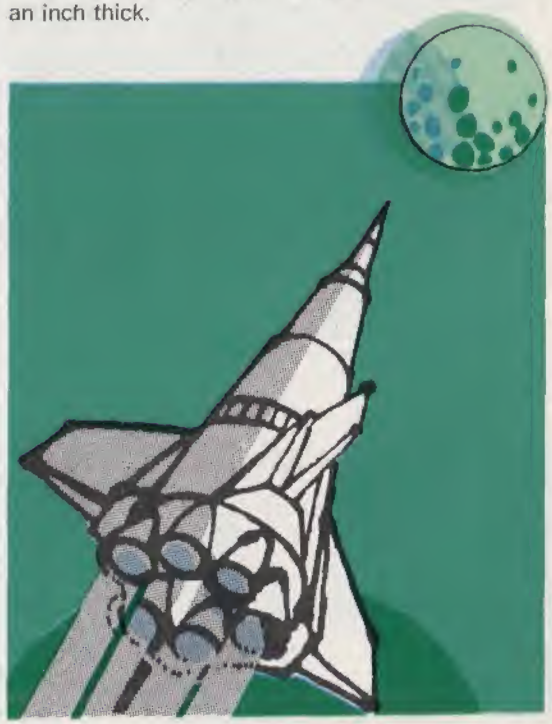
Aluminum's lightness is one part of the story. Every extra pound of weight at lift-off calls for thousands of pounds of additional thrust, but the saving extends beyond that. Each pound of weight saved means less fuel required, which means less fuel weight, which means still less fuel required. You can chase this like a repeated image in two opposite mirrors, but design engineers get the idea.

Aluminum has, however, more than lightness to offer. It can be formed readily into the intricate and unprecedented shapes that go into a missile. Its reflectance turns back the sun's heat.



Project Haystack is the most advanced radio signal instrument of its kind in the world. Located on a hill in Massachusetts, this research facility will help to build a store of information to be used in developing large ground-based transmitting and receiving equipment required to operate world-wide communications systems. The antenna required the most precisely built reflector of its size ever attempted and took 150,000 pounds of aluminum honeycomb sandwiched between aluminum sheets. In all, construction of the big dish and its protective radome required 350,000 pounds of aluminum. The device is capable of spotting a quarter-inch metal slug at a distance of 1,000 miles in space.

The largest man-made satellite ever sent aloft was also the least expensive. Echo II measured 135 feet across, large enough to be seen easily from the ground with the naked eye. Offering 82 percent more reflective surface than Echo I, the great balloon's skin was made of aluminum foil laminated to plastic. The foil measured only 18/10,000 of an inch thick.

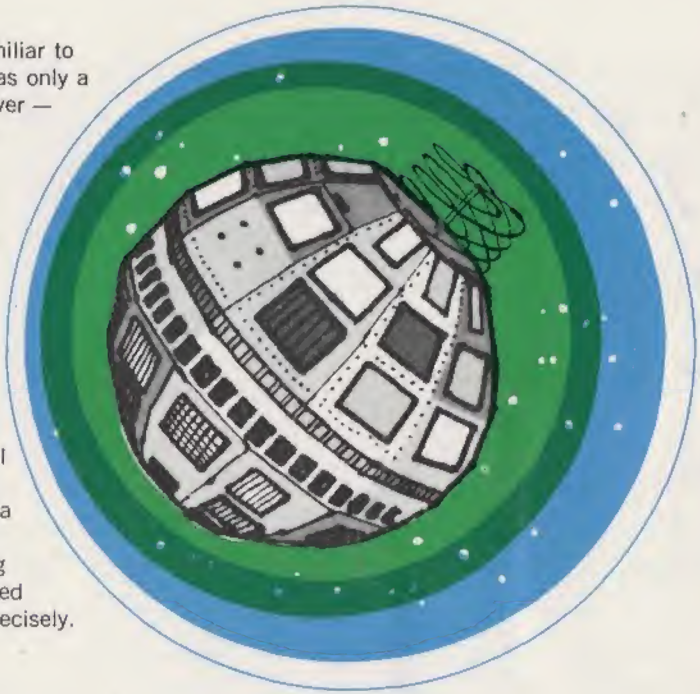


And its superior buckling efficiency withstands the stresses engendered when a missile rapidly becomes a spear hurtling away from the earth at 17,000 miles per hour. The most obvious aerospace uses of aluminum lie in vehicle structures and skins, in fuel and oxidizer tanks, and in castings for electronics gear.

Aluminum powder contributes to blastoff as an ingredient in solid fuels. Saturn V will require 400,000 pounds of aluminum in its first stage, in forty 10,000-lb pieces of plate used for tank skin. There's more in the form of "Y" rings machined from 15,000-lb pieces of aluminum for the huge circles to which the skin and the end domes of the first stage will be joined, and 100,000 pounds of sheet and plate for the second stage.

And don't forget the ground support area. Aluminum is used in the fashioning of simulation models, it goes into the tracking devices and in much of the electronic gear stationed around the missile launch centers.

By now, Telstar is familiar to most Americans. It was only a short time ago, however — July 10, 1962 — that the satellite's first television pictures were received on earth, bounced back after transmission from a station in Maine. The feat was made possible by a 50-foot-long antenna capable of rotating in both horizontal and vertical planes. The funnel portion of the antenna uses 80,000 pounds of aluminum, allowing the device to be moved quickly, easily and precisely.



Since 1950, the use of aluminum has increased about 250 per cent as American consumers and industries have found new applications for the metal at a startling pace. Around the home, inside factories, in the sky, on water, in combat, on the highways, in the kitchen — wherever you look — aluminum is there doing its job with a versatility that no other material can match. And in many areas, its potential is just being realized. For producers, fabricators and users of aluminum, the future is as bright as the metal itself.

Jules Verne, in his prophetic *From the Earth to the Moon,* (published in 1865), hit on aluminum as the perfect material for sending men outside the earth's atmosphere. One of his characters put it this way: "It is easily wrought, is very widely distributed, forming the basis of most of the rocks, is three times lighter than iron, and seems to have been created for the express purpose of furnishing us with the material for our projectile."

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